Popular Astronomy

Vol. LIX, No. 9 NOVEMBER, 1951 Whole No. 589

The Motion of the Moon

By PAUL E. WYLIE

The crudest of observations show that the Moon moves along its orbit among the stars at a variable rate. For about two weeks, the Moon's motion is variably faster than its average rate, and for a similar but unequal period in each circuit, its motion is slower. It seemed necessary to ancient observers that the Moon's orbit be circular and that its rate of progress be uniform; consequently they explained these changes in angular velocity by displacing the Earth from the center of the lunar orbit by a distance just sufficient to account for the changes. The correction thus made was only approximate, because the Moon's orbit is not circular, but elliptical. The difference, however, between an eccentric circle and an ellipse of small eccentricity is small, and escaped ancient observation. This most obvious of the inequalities in the Moon's sidereal motion is called the "equation of the center." We explain it nowadays in terms of Kepler's laws. We say that the Moon's unperturbed orbit is an ellipse, with the Earth at one focus, and that the Moon's progress in this orbit is variable, the velocity being greatest at perigee and least at apogee, in accordance with Kepler's law of areas.

So far we have considered the Earth and Moon alone; but the Sun must be taken into account. The varying directions of the Sun and the Moon, seen from the Earth, cause the phases of the Moon. We need not pursue the subject of the phases beyond stating that when the Sun and Moon are in conjunction, we have a "new Moon"; when they are in opposition, a "full Moon." Without assuming that the line of apsides of the Moon's orbit is fixed in direction (and we shall later see that it is not), it is evident that, as the Earth revolves around the Sun, the line from Earth to Sun will make varying angles with the line of apsides of the Moon's orbit. This variation causes changes in the timing of the Moon's phases and in the times of the consequent tides of the sea. In Fig. 1, the Moon's orbit is shown with its major axis perpendicular to the Sun's direction. New Moon is at A; the following full Moon, at B. A and B are 180° apart, but the time interval from A to B is less than that from B to A; not only because of the difference in length of arc, but because, according to Kepler's law of areas, the Moon's orbital speed is greater near perigee; that is, from A to B. At some other time, the orientation of the orbit relative to the Sun's direction will be reversed; then the time from new Moon to full Moon will exceed that from full to new. When the lunar major axis coincides in direction with that of the Sun, the two intervals will be equal. The maximum

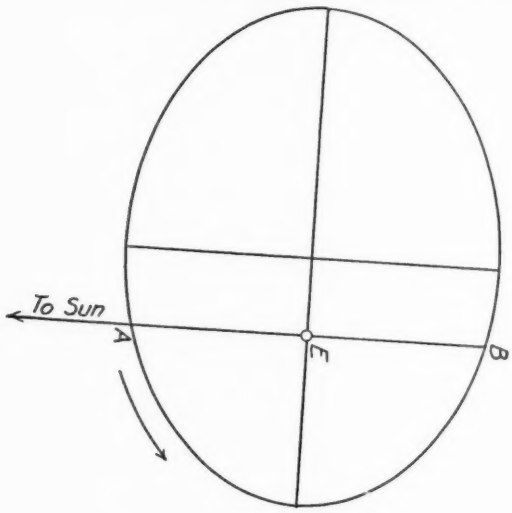


FIG. 1

difference approximates three days, and was explained by the ancients as a consequence of the equation of the center. We explain it in nearly the same manner, substituting an ellipse for the eccentric circle, and involving Kepler's second law. The phases involve the Moon's synodic motion. Hereafter, we shall be involved with the Moon's sidereal motion; the Earth always remaining in the center of the sky. We might alternatively say that the orbital motion of the Earth may be neglected in discussing the motion of the Moon relative to the stars, due to the stars' vast distances.

The presence of the Sun produces gravitational effects on the Moon's motion; but first, imagine that the Earth and the Moon exist alone in space. The Moon will then revolve around the Earth in a true ellipse, as shown by the solid curve of Fig. 2, with the Earth, E, on the major axis, at one focus. The Moon is forced to describe its elliptical orbit by the gravitational force exerted by the Earth. This force causes the Moon to be continually accelerated toward the Earth, away from the straight line which, according to Newton's first law, it would otherwise follow. If, now, some other source of gravitational force, such as the Sun, is introduced, the Moon's orbit will be changed because of the difference in the accelerations, due to this new force, affecting the velocities of the Moon and of the Earth. Both Moon and Earth are free to move under the Sun's attraction; any change in the Moon's originally elliptical motion is due to the fact that the Earth and the Moon are unequally accelerated by this force. This inequality of accelerations is due solely to the fact that Earth and Moon are unequally distant from

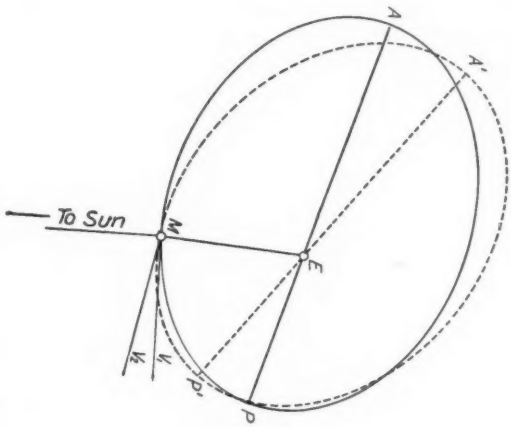


FIG. 2

the Sun, and (unlike the forces involved) is not affected by the masses of the two bodies. This independence of accelerations of the masses may be shown by the Law of Gravitation, $F = GMm/d^2$, where F is the Sun's force of gravitational attraction, G is the universal constant of gravitation, M is the mass of the Sun, m is the mass of the body considered, and d is the distance of that body from the Sun. Newton's second law of motion states that, for any force, $F = ma$, where "a" is the acceleration. Substituting this value of F in the preceding equation, we have $ma = GMm/d^2$. The mass "m" cancels out, showing that the acceleration due to gravitation depends solely upon the distance of the body involved from the Sun. Applying this conclusion to the Earth and the Moon, it is evident that the acceleration of each of these two bodies depends only upon the body's distance from the Sun, and that the nearer body will have the greater acceleration. In a picture of the positions and motions of the Moon relative to the Earth, therefore, only the *difference* between the Sun's gravitational acceleration of the Moon and that of the Earth is effective in changing the geocentric orbital path of the Moon. It is to this difference in accelerations that we shall hereafter refer when we mention an "acceleration" in connection with lunar motion relative to the Earth.

If the plane of the Moon's orbit coincided with that of the Earth, the accelerations due to the Sun would be confined to the orbital plane. The Moon's orbit, however, makes an angle of about 5° 8′ with the Earth's orbital plane, so that the Sun's attraction is applied at an angle to the lunar orbit plane. We wish, however, to consider the motion of the Moon relative to its own orbit; consequently, the solar acceleration may be resolved into three mutually perpendicular components, viz.: (a) a *normal* component, in the plane of the lunar orbit, and perpen-

dicular to the instantaneous direction of the Moon's motion; (b) a *tangential* component, in the plane of the lunar orbit, parallel to the instantaneous direction of the Moon's motion; and (c) an *orthogonal* component, perpendicular to the plane of the Moon's orbit and consequently perpendicular to components (a) and (b). It will be convenient to discuss the effects of these components of the acceleration separately, remembering that the actual acceleration of the Moon's velocity will be the resultant of the accelerations due to the three components.

In order to discuss the normal acceleration, it will be convenient so to arrange matters that the tangential acceleration is absent. Having the unperturbed lunar orbit—the solid curve of Fig. 2—with the Moon at M and the Earth at E, the Moon's velocity is represented by V_1. The velocity V_1 is a vector; the length thereof is proportional to the speed according to some convenient linear scale, and the direction of the vector is the instantaneous direction of the Moon's motion; that is, the direction of a tangent to the ellipse at the Moon's position. The magnitude and direction of V_1 continually change at various points in the orbit, as the acceleration due to the Earth's attraction changes with varying distance of the Earth. In Fig. 2, a moment has been selected when V_1 is perpendicular to the direction of the Sun, and when the Moon is nearer to the Sun than is the Earth. Under these conditions, the Sun's attraction will produce an acceleration of M in the direction perpendicular to V_1. This acceleration will not therefore change the speed (the magnitude of V_1), but will produce only a change in the direction of the Moon's motion; that is, the velocity will now be shown by the vector V_2, in the limiting instantaneous case. It is seen that V_2 is equal in length to V_1. How has the application of the acceleration affected the lunar orbit? The Moon is at the same distance from the Earth; it is also moving at its original speed. It is, however, tending to move in a new direction. This direction must be tangent to a new orbit at M, shown in the dotted ellipse of Fig. 2. The dotted ellipse of Fig. 2 is, however, incorrect; further change is necessary. After the rotation of the line of apsides has taken place to produce the tangency of V_2, it is seen that M is nearer to the new perigee P′ than it was to the original perigee, P. Evidently, to satisfy Kepler's second law, since V_2 is fixed in magnitude, something more than a simple rotation of the line of apsides is required to make the velocity V_2 consistent with the rotated orbit. Two possibilities exist: (a) a change in the length of the major axis of the orbit; (b) a change in the orbit's eccentricity. Let us consider (a) first. There is a general law of orbital motion, stated in the form of the "equation of energy"; $V^2 = K\,(2/r - 1/a)$, in which, for our case, $K = G\,(m_e + m_m)$, "r" is the distance EM between Earth and Moon, and "a" is the semi-major-axis of the lunar orbit. For the circumstances we are considering, V, (that is V_2), "r" and "K" are not affected at the instant by the applied acceleration. In order that the equation may balance, "a" must be constant also; that is, the major axis remains un-

changed. By elimination, then, it follows that the eccentricity of the orbit must change in such a manner as to make V_2 the correct Keplerian velocity at the point M in the new orbit. (We have not attempted to show the orbit of changed eccentricity in the figure.) It is necessary to conclude from the discussion that an acceleration applied to the Moon in a direction normal to the Moon's velocity will produce a change both in the orientation of the line of apsides and in the eccentricity of the lunar orbit, without change in the length of the major axis.

The changes are obviously non-uniform; only in a special case is the whole acceleration perpendicular to the direction of the Moon's motion; moreover, the acceleration itself varies with varying distance of the Sun and with the magnitude of the orthogonal component. The solar distance is affected in two manners: (a) at full Moon the Moon is more distant than is the Earth from the Sun, so that the solar acceleration of the Earth is the greater; at new Moon the opposite is true; (b) there is a changing ratio of Earth-Moon and Earth-Sun distances throughout the year, due to the eccentricities of the Earth's and the Moon's orbits.

What is the effect of the tangential component—that component of the Sun's acceleration which is in the direction (or contrary to it) of the Moon's orbital motion? Fig. 3 shows the Sun's attraction acting in

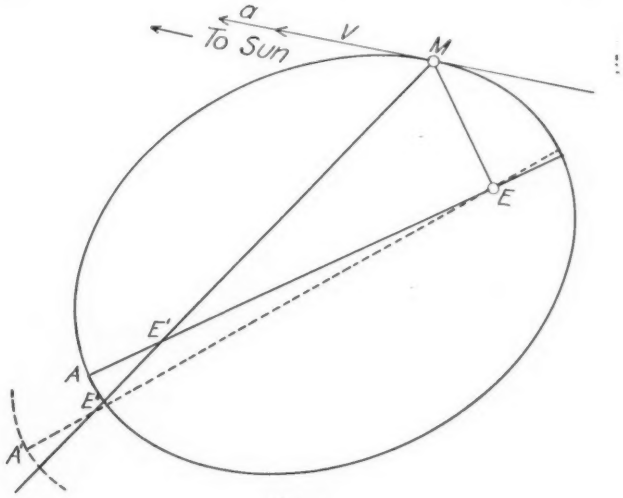


FIG. 3

the same direction as the Moon's orbital velocity. The corresponding acceleration to the Moon's motion will therefore act, not to change the direction of the Moon's motion, but to speed it up. Referring again to the equation of energy, it is seen that V has been changed; that there has been no change in "r." It follows that "a," the semi-major-axis,

must have been increased by the acceleration, in order that the equation may balance. This seems logical on intuitive grounds. It is evident that if the Moon's velocity at M is increased, the Moon will proceed farther from E before slowing down to a radial stop at apogee under the influence of the Earth's negative acceleration. In other words, the length of the major axis will be increased, and so, in consequence, will be the eccentricity of the orbit. Fig. 3 (adapted from Moulton) presents the situation from the geometrical viewpoint. From the geometry of the ellipse, the lines EM and E′M must make equal angles with the tangent at M. This is true both in the unperturbed and in the perturbed orbits. In the perturbed orbit, E″, the new unoccupied focus, must lie, then, on E′M beyond E′. The new apogee is indicated at A′ and the new major axis is shown dotted through E and E″. So, not only does the tangential component of the solar acceleration produce a change in eccentricity and in major axis, but it, like the normal acceleration, produces a rotation of the line of apsides; in our figured case, an advance.

It is evident that the two causes of rotation of the line of apsides may work together or in opposite directions under varying conditions, so that the rate is highly variable. In the long run, however, the rotation is direct—easterly—in a period of about 8.85 years. The changes in eccentricity are also variable in rate; however, the long-term effects of eccentricity changes just about balance; the eccentricity of the Moon's orbit fluctuates, but in the long run, it will be in the neighborhood of 0.055, its mean value. The change in the rate of motion of the Moon, accompanying changes in eccentricity, is called the "evection." Its existence was discovered shortly before 150 B.C. by Hipparchus. In effect, the evection may be described as a periodic variation in the amount of the equation of the center; when the Sun lies in the line of apsides, the eccentricity of the lunar orbit is increased; when the line of apsides lies in quadrature, the eccentricity is diminished.

When the Moon is in conjunction, the Sun's acceleration is greater on the Moon than on the Earth; when in opposition, the reverse is true. In both cases of syzygy, therefore, there is a decrease in the orbital geocentric acceleration. When the Moon is at quadratures the solar accelerations of the Sun and of the Moon would be equal if the lines Earth-Sun and Moon-Sun were parallel, but due to the slight convergence of these lines, a small increase in geocentric acceleration is contributed by the Sun. The result is an inequality called the "variation," discovered by Tycho Brahe. Like the evection, the variation is a cyclic effect produced by accelerations in the plane of the Moon's orbit.

Except for the variation, the solar acceleration tends thruout the month to decrease the Moon's geocentric acceleration. At conjunction, the solar acceleration on the Moon exceeds that on the Earth, and tends to cause a withdrawal of the Moon from the Earth; at opposition, the acceleration of the Earth is the greater, again causing an increase in the Moon's distance. The result is that the Moon is more distant from

the Earth than it would be if the Sun were absent, and that, according to Kepler's harmonic law, the Moon's period is increased. Due to the presence of the Sun the month is about 53 minutes longer, on the average, than it would otherwise be. Any decrease in solar acceleration of the Moon would result in a decrease in the Moon's geocentric distance, and a decrease in the Moon's sidereal period, again in obedience to Kepler's third law. The amount of the actual increase in the sidereal month due to the Sun depends upon the distance of the Sun; the more distant the Sun, the less the effect.[1] The changing distance of the Sun during the year thus leads to an inequality called the "annual equation."

Edmund Halley discovered by study of ancient eclipse records that the sidereal month is steadily and very slowly becoming shorter. For a long time this "secular acceleration of the Moon's motion" remained unexplained, although the fact could not be doubted. The explanation is due to Laplace. We have seen that the length of the sidereal month is increased by the solar acceleration; also, that the amount of the solar acceleration is greatest at least solar distance and least at greatest solar distance. Variation in solar distance is due to the eccentricity of the Earth's orbit. So, if the eccentricity of the Earth's orbit were to change, the solar accelerations on the Moon would change also. It is an observed fact that, because of planetary perturbations of the Earth's motion, the eccentricity of the Earth's orbit is slowly decreasing. As the orbit becomes more nearly circular, the *average* distance of the Earth-Moon system from the Sun is thus increasing, even though the "mean distance"—one half the major axis of the Earth's orbit—is unaffected. We have seen that the effect of this increase in solar distance would be to decrease solar accelerations, thus effectively to increase the geocentric acceleration, and thus to reduce the distance of the Moon from the Earth, and to increase the Moon's orbital velocity, as required by Kepler's third law. The increase in velocity and reduction in distance result in the observed decrease in the Moon's sidereal period. The change in the eccentricity of the Earth's orbit is cyclic. After attaining in the remote future almost perfect circularity, the eccentricity of the Earth's orbit will again increase, and the Moon will increase its period and withdraw.

It remains to discuss the effects on the Moon's motion of that component of the acceleration due to the Sun's attraction which is perpendicular to the plane of the Moon's orbit. It is evident that this component would be zero if the plane of the Moon's orbit around the Earth

[1] The sensitivity of the geocentric acceleration to changes in the Sun's distance may be illustrated by a gross imaginary example. Imagine two pairs of Earths and Moons, each separated by unit distance. The first pair are at respective distances 4 and 5 units from the Sun; the second pair at distances 9 and 10. Finding the geocentric acceleration we have for the first pair, $a = GM/16\text{-}GM/25$, and for the second pair, $a = GM/81\text{-}GM/100$. The ratio of these respective accelerations is about 9.6; that is, by approximately doubling the solar distance, the negative geocentric acceleration of the Sun on the Moon is reduced to little more than 1/10 its original amount.

coincided with the plane of the Earth's orbit around the Sun. In fact, it does not coincide; there exists an angle of about 5° 8′ between the two planes. This is shown pictorially in Fig. 4, in which the large square

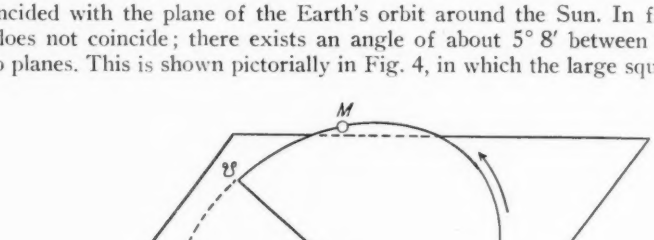


FIG. 4

is a piece cut out of the plane of the Earth's orbit. About one-half of the Moon's orbit—shown by a solid line—lies north of the Earth's orbit plane, and the other part, shown dotted, lies south of that plane. At two points in the lunar orbit the Moon lies momentarily in the plane of the Earth's orbit. These points are called the "nodes"; ascending, ☊, when the Moon crosses the Earth's orbit from south to north; descending, ☋, when the Moon passes from north to south. The line joining the nodes —the intersection of the two orbit planes—is called the "line of the nodes." Fig. 5 is a section through the two orbit planes, perpendicular

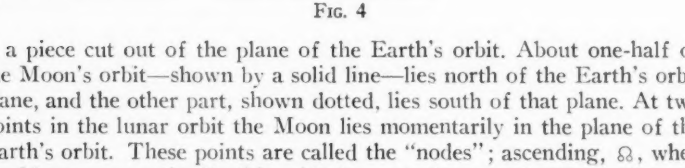


FIG. 5

to the plane of the Earth's orbit, and also perpendicular to the line of nodes. The section is consequently also perpendicular to the plane of the Moon's orbit. (The angle between the planes has been exaggerated in the figure.) The Moon is shown at its maximum distance north of the Earth's orbit. Consider first the case in which the Moon is in conjunction in this attitude; that is, the line of nodes is perpendicular to the Earth's radius vector. The Sun is at so great a distance (to the right) that its attractive force is applied nearly parallel to the Earth's orbit plane. In the figure we have resolved the resultant net acceleration into two components; one lying in the plane of the Moon's orbit, and the

other perpendicular thereto. The first component (in resolution) has been discussed; it remains to examine the accelerations due to the orthogonal component. If the Moon were at rest, this component would pull the Moon "down" into the plane of the Earth's orbit. It does, indeed, produce a velocity in that direction, but this velocity is combined with the Moon's orbital velocity to produce the actual effect, which is that the node will be reached before it would be were this acceleration absent, and the position of the node will be displaced toward the west; geometrically, the lunar orbit is twisted around toward the west, without changing the inclination between the two orbit planes. This effect is the same as that producing precession in a gyroscope; the Moon may be considered as a gyroscope consisting of one particle instead of a multitude of particles forming a wheel. This "regression of the nodes" is analogous to the gyroscopic effect of the Moon's attraction on the Earth's equatorial bulge, called the precession of the equinoxes. In the latter case, however, we have a complete "wheel," which fact eliminates the perturbation of the axis of gyroscopic rotation about the center of mass of the system. This is present in the Earth-Moon system, and causes the Earth to depart slightly from its Keplerian elliptical orbit.

The regressive acceleration varies, and so, consequently, does the rate of regression of the nodes. When the Moon is at a node, the regressive acceleration vanishes; it rises to maxima about midway between the nodes; it varies with the direction of the line of nodes relative to the Earth's radius vector; it varies with the Earth-Moon distance from the Sun. Finally, we must take into account the direction of the Sun, instead of approximating that direction in a line parallel to the plane of the Earth's orbit. Though the rate of regression thus varies, the net result is a westerly movement; one complete rotation of the line of nodes takes place in about 18.6 years.

By definition, the orthogonal component can have no effect in the plane of the Moon's orbit. It cannot change the eccentricity, the orbital velocity, or the orientation of the line of apsides; all of these changes require accelerations in the plane of the Moon's orbit.

It may be of interest to review the subject of the regression of the nodes with the help of a diagram. In Fig. 6 (adapted from Moulton) AB is the plane of the Earth's orbit. The Moon is moving upward and toward the right—toward Ω_1, the ascending node—along the line CD.

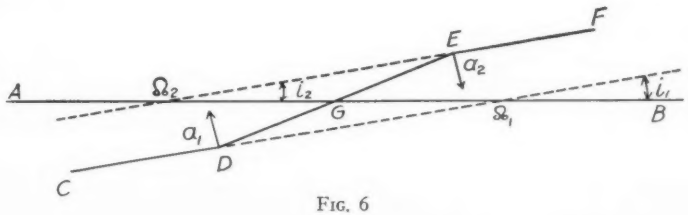


FIG. 6

The inclination of this path is the angle i_1. At D we apply the instantaneous orthogonal component of the Sun's acceleration in the vector a_1. The Moon will, under its original velocity and this acceleration, pursue the path DE. It should be noted that the orthogonal component is always directed toward the plane of the Earth's orbit, since the Sun lies in that plane, and is endeavoring to draw the Moon down into it. So, when at E, equidistant with D from G, the orthogonal acceleration is again introduced, it, a_2, will be directed downward as shown. Since the Sun's distance, if DE is short, has not been sensibly changed, then $a_1 = a_2$, and the result of applying a_2 will be to change the Moon's path into the line EF, parallel to CD. The final inclination i_2 is the same as i_1, but Ω_2 lies west of Ω_1. To complete the representation, we need only imagine infinitely many pairs of accelerations, symmetrically spaced about G, thus producing a continuous acceleration. It appears that the orthogonal component causes no change in the inclination; it does change the orientation of the plane of the lunar orbit, causing the line of nodes to regress toward the west. Small cyclical variations of "i" do, however, appear. These may be explained by assuming that the points D and E are at great distance from G, since then a_1 is unequal to a_2, because of the difference in the distance of the Sun when the Moon is at D and at E.

Our elementary discussion of the motion of the Moon has produced only qualitative results. These results may be useful in more advanced study, or, for some, they may suffice. Quantitative results in this field are actually achieved, not by geometric but by algebraic treatment. Lunar theorists would be happy if a quantitative solution involving the variables we have discussed sufficed to exhaust the subject of lunar motion; but this is not so. Other gravitating masses than Earth, Moon, and Sun must be taken into account. Such masses exist in the planets and in the equatorial bulge of the Earth. The effects produced are small, being, as they are in the case of the planets, due to the difference between planetary perturbations on the Earth and those on the Moon, but they are not negligible. The complete lunar problem is one of the most involved in the whole realm of applied mathematics.

Study of lunar motion, where the perturbations due to the Sun are large and easily visualized, leads to a general understanding of the perturbations of the planets. The principles involved are identical in both studies.

The author wishes to thank Dr. Samuel Herrick for his critical reading of the manuscript.

Department of Astronomy, University of California, Los Angeles 24, California.

Regiomontanus*

By EDELBERT BRAND

There is a small, secluded town in Bavaria, of about 1,600 inhabitants, charming and enchanting, a part of the Main Valley, leaning towards the ascending range of the Hassberge, called Koenigsberg in Franconia. This place must not be mistaken with Koenigsberg in East Prussia, the home of the great philosopher Immanuel Kant. The first was founded by Archduke Ulrich of Carinthia in 1180.

Touring this lovely place one feels engulfed by an insinuating medieval air, blended with modern snugness. Art treasures of more than local significance attract the visitor, such as the church of Our Lady, in most representative architecture, done in an elegant Gothic style, and the Watchmaker's house, a splendid specimen in frame wood with rich carvings. Myth and stories wind and wreathe around this town's 800-year-old past as an unfading classical sleeping beauty.

However, if Koenigsbergers are proud of their long and eventful past then foremost in this record is the name of Camillus Johannes Mueller who was born there on June 6, 1436. He called himself Johannes de Monteregio, derived from the Latin name of his birthplace. Later his name became modified into Regiomontanus.

His birthplace, now under the custody of the town council, is a two-story frame wood structure with neat-looking glittering oriel windows, located at the Salt Market. A sandstone fountain monument at the Market Place presents every stranger with the name and fame of this great scholar.

Regiomontanus' life covered a span of forty years. This period on earth was far too short to pour out his rich intellectual gifts for the enlargement and deepening of our knowledge.

He commenced his university studies at Leipzig. At the age of fifteen, he was a student of the renowned mathematician Georg Peuerbach at Vienna, in 1451. Here, as a young scholar, he delivered various speeches on mathematical subjects, which won him increasing notice. Jointly with Peuerbach he undertook a reform of astronomic calculations and evaluations which had become necessary on account of several errors these two scholars had detected in the Alphonsine Tables. They based their research studies partially on works of Ptolemy who was the noted advocate of the geocentric world view for a millenium and a half following his death in 161 A.D. For want of a correct translation of Ptolemy's writings, the progress of the reform studies was considerably

*This year the 475th anniversary of his death is being commemorated. This is the thirteenth in the series of "Papers in Historical Astronomy." (The twelfth paper in the series—"Robert Hooke as an Astronomer," by Angus Armitage—appeared in the June, 1951, issue of POPULAR ASTRONOMY.)

hampered. In order to overcome this bottleneck, Regiomontanus decided to learn Greek. He accompanied the Greek-born Cardinal Bessarion to Italy in 1461 where he acquired Greek rapidly. Soon, he became able to translate such writings as Apollonius' *Conica,* Serenus' *Cylindrica,* Heron's *Pneumatica,* and Aristotle's *Problems of Mechanics.* He also lectured on Alfraganus at Padua. At Venice, he completed Peuerbach's *Epitome in Cl. Ptolemaei Magnam Compositionem* in 1463, which was printed only twenty years after his death at Venice in 1496. There, he also wrote his famous *De Triangulis Omnimodis,* an elaborate treatise on Trigonometry, printed at Nuremberg in 1533.

After his return from Italy in 1468, he was called to the court of Mathias Corvinus, king of Hungary, to examine some Greek manuscripts. At that time, he also finished his *Tabulae Directionum Profectionumque in Navitate Multum Utiles,* Nuremberg, 1475. Though being essentially an astrological writing it contains his valuable table of tangents.

Back from Hungary, he settled down in Nuremberg, then a town of about 25,000 inhabitants. There, he coöperated with the wealthy patrician Bernhard Walther who was both his student and patron. To become independent of publishers' peevishness, he established a printing press of his own, which soon became known for the accuracy of its prints. Further, he erected the first observatory in Germany. His findings in Trigonometry helped much in the progress of this science. He introduced the tangents and divided the protractor into ten million parts. Also in Mechanics he deepened the knowledge of his time by new cognitions. He was unwearied in his efforts to introduce the study of Algebra in Germany.

His world fame, however, was the result of his astronomical calculation. Two of his writings must be mentioned in this respect: *Peuerbach's Theoriae Planetarum Novae* and *Ephemerides ad* XXX *Annos Futuros 1475-1506,* Nuremberg, 1474. The latter was an accurate calculation of extraordinary keenness. It proved of such good use that the *Ephemerides* were handed to Columbus by his disciple Martin Behaim who was engaged to improve the art of navigation at Lisbon from 1481 on. Other navigators, such as Ferdinand Magellan and Vasco de Gama, also made use of Regiomontanus' nautical instruments such as the meteroscop, the torquotum, and the James' staff.

Regiomontanus sharply challenged Cardinal Cusanus' statement wherein he claimed to have found the Quadrature of the Circle. Remarkable were his observations of the great comet in 1472, later on called Halley's. He is the founder of the modern study of comets outlined in his *De Cometae Magnitudine et Longitudine,* Nuremberg, 1531. Halley's comet, which is due to appear every seventy-five years, visited us last in 1910 and is due to return in 1985. In 1453, when the Turks had captured Constantinople, widespread apprehension seized the world that the Turks might succeed in conquering the whole of the Christian

nations. When Halley's comet appeared in 1460, this fear rose to its climax.

Upon the summons of Pope Sixtus IV, Regiomontanus went to Rome in 1475 to assist him in reforming the old Julian calendar. This was a preliminary step to the great reform directed by Pope Gregory XIII in 1582. Sixtus IV awarded Regiomontanus the nominal bishopric of Ratisbon, although he was not a theologian. He died in Rome on July 6, 1476, swept by the plague which afflicted the town with the yearly inundations of the Tiber. His body rests in the Pantheon in Rome.

Beside an unusual sharpness of judgment, Regiomontanus displayed an excellent acumen and an extensive versatility in science, a statement which may be verified by the great variety of his painstakingly written works as for instance on the "Burning Mirror," "Water Work," "Weight," and many others. His patron Bernhard Walther bought from property left at his death instruments and writings and continued the astronomical observations begun in the *Ephemerides*. So Regiomontanus' scientific accomplishments outlived his actual life-span. They were passed on to his famous disciples as a blazing torch: to Martin Behaim and to the Italian astronomer Domenico Maria Novara, whose disciple Nicholas Copernicus replaced the geocentric world view by the heliocentric.

So Koenigsbergers as well as the scientific world remember the 475th anniversary of Regiomontanus' death with a grateful mind recalling that he gave mankind a deeper insight into the secrets of the universe.

University of Maryland, Overseas Branch, Wurzburg, Bavaria, U. S. Zone, Germany.

The Periods of Planets and Moons

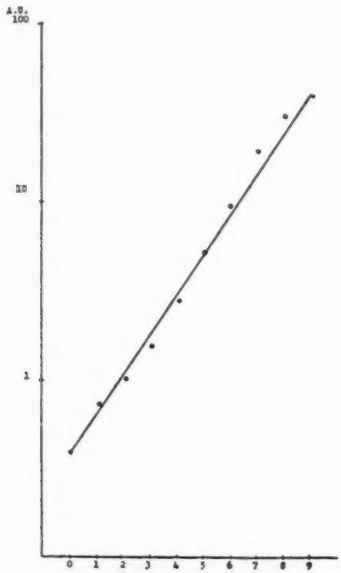
By SIDNEY VAN DEN BERGH

Ever since the time of Kepler, attempts have been made to find some law or empirical relation that would give the distances of the planets from the sun. The best known of these is the relation proposed by Titus and Bode in 1772. However, this rule breaks down for Neptune and Pluto and must therefore be disregarded. We therefore wish to investigate if any regularity exists in the distribution of planets and moons.

On making a semi-logarithmic plot of the distance of the secondary versus the order number of the secondary we find that there is a definite similarity between the satellite systems of Jupiter, Saturn, Uranus, and the Sun. Graph 1 gives such a semi-logarithmic plot for the Solar system. It is found from such a plot that to a first approximation the semi-major axis of the nth secondary is given by a relation of the form

$$D(n) = A^n \qquad (1)$$

where $A = 1.69$ for the solar system if all distances are expressed in



GRAPH 1

terms of the semi-major axis of Mercury. In other words: D(Mercury) = $(1.69)^0$, D(Venus) = $(1.69)^1$, D(Earth) = $(1.69)^2$, etc.

We shall now have to investigate the deviations from this first approximation. It seems that these deviations might in part be caused by the mutual perturbations of the secondaries. In this case the deviations may be similar to the readjustment of periods of the asteroids found by Kirkwood in 1885.

To see if such an effect exists we have computed* the ratios of the periods of (secondary (n + 1/secondary n). The results are tabulated below and shown in Graph 2. It will be seen from the table that all but

GRAPH 2

TABLE

Planet n,	Planet n + 1	Ratio of periods	
SUN			
Mercury	-Venus	2.56	(5/2)
Venus	-Earth	1.62	(3/2)
Earth	-Mars	1.88	(4/2)
Mars	-Astr.**	2.50	(5/2)
Astr.	-Jupiter	2.52	(5/2)
Jupiter	-Saturn	2.49	(5/2)
Saturn	-Uranus	2.85	(6/2)
Uranus	-Neptune	1.96	(4/2)
Neptune	-Pluto	1.50	(3/2)
MARS			
Phobos	-Deimos	3.96	(8/2)
JUPITER			
V	-Io	3.55	(7/2)
Io	-Europa	2.01	(4/2)
Europa	-Ganymede	2.01	(4/2)
Ganymede	-Callisto	2.33	(5/2)
6(mean)	-8(mean)	2.85	(6/2)
VI	-VII	1.04	(2/2)
VII	-X	.98	(2/2)
VI	-X	1.01	(2/2)
VIII	-IX	1.01	(2/2)
IX	-XI	.93	(2/2)
VIII	-IX	.93	(2/2)
SATURN			
Ring rim	-Mimas	apr. 1.58	(3/2)
Mimas	-Enceladus	1.45	(3/2)
Enceladus	-Tethys	1.38	(3/2)
Tethys	-Dione	1.45	(3/2)
Dione	-Rhea	1.65	(3/2)
Rhea	-Titan	2.83	(6/2)
Titan	-Hyperion	1.33	(3/2)
Hyperion	-Iapetus	3.73	(?)
URANUS			
Miranda	-Ariel	1.79	(?)
Ariel	-Umbriel	1.65	(3/2)
Umbriel	-Titania	2.10	(4/2)
Titania	-Oberon	1.54	(3/2)

Note: 6(mean) = Mean distance of VI, VII, and X;
8(mean) = Mean distance of VIII, IX, and XI.

two of the period ratios are close to: 2/2; 3/2, 4/2, 5/2, . . . and that with these two exceptions the following ratios are absent: 3/4, 5/4, 7/4, 9/4, . . .

Kirkwood found that minor planets avoid places which correspond to some degree of commensurability with the motion of Jupiter. But Kirkwood's data were limited to those parts of the whole system having motions greater than 500″ (per day), that is to a ratio of mean motions less than 3/5. There are today a number of asteroids known with motion less than 500″, and if we consider these we find, surprisingly

enough, that places where the ratios are 1/1, 2/3, and 3/4 are actual clusters of planets (asteroids) instead of gaps.***

It therefore seems that we may conclude:

1: To a first approximation planetary distances and the distances of moons are given by an equation of the form of eqn. (1).

2: These distances are readjusted by some kind of a resonance effect.

It is, however, not clear if this ordering took place at some time during the creation of the solar system or at a time when the solar system was more or less in its present state.

REFERENCES

*Original data taken from *B.A.A. Handbook*, 1949.
**For an asteroid distance of 2.8 A.U.
****J.B.A.A.*, Vol. 61, No. 1, p. 10 (December, 1950).

OHIO STATE UNIVERSITY, JANUARY 15, 1951.

Contributions of the Meteoritical Society

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

Applications of Autoradiographic, Tracer, and Other Modern Nuclear Techniques in Meteoritics*

LINCOLN LAPAZ
Institute of Meteoritics, University of New Mexico, Albuquerque

ABSTRACT AND INTRODUCTION

The metals of the recovered meteorites pose, in addition to all of the complex questions encountered in the metallurgical and metallographic study of the industrial alloys, many difficult problems stemming out of the peculiar manner in which the meteorites originated and the unusual conditions to which those bodies have been subjected thruout the course of their history, both before and after their collision with the Earth's atmosphere.

The *classical* investigations of the meteoritic metals, following lines already well established by metallurgists, were carried out by the use of *oblique* illumination and relatively low magnifications. Altho the invention of the method of *vertical* illumination was made nearly a century ago, and soon led to remarkable advances in metallurgical knowledge, nevertheless its application to the study of meteorites was inexplicably delayed; and, indeed, it was only with the appearance of S. H. Perry's recent monograph[1] that the effectiveness of the techniques of

*Read by title at the 14th Meeting of the Society, Los Angeles, California, 1951 June 18-19.

modern metallography as applied to meteoritic irons and the significant results obtained thru such applications became readily accessible to American meteoriticists.

Powerful as are modern metallurgical methods, so difficult are the questions posed, not alone by the siderites (SI), but also by the aerolites (AE), and particularly by the siderolites (SO), that there is urgent need for yet more sensitive, flexible, and effective research techniques, if the studies of the meteoriticist are to be brought to a successful conclusion. Recent developments in nuclear physics and in allied fields provide precisely such techniques, and it is the purpose of this paper to call attention to them and to certain problems in meteoritics to which they are applicable. Since optimum results from the use of some of the research techniques in question are possible only if they are employed on meteorites immediately after their fall, sufficiently detailed instructions are given to enable those fortunate enough to collect freshly fallen meteorites to investigate them properly. Brief reports are given on several meteoritical investigations now being conducted by the use of these most modern research techniques. The results so far obtained by these new methods furnish the strongest possible argument for their wider adoption by those conducting research on meteorites.

PART I: AUTORADIOGRAPHIC AND ALLIED TECHNIQUES

Historically, the oldest of the methods to be discussed is the autoradiographic, for, insofar as *natural* radioactive substances are utilized as the photographic agent, the method has been available for investigation of meteorites ever since the time of Becquerel. Possibly because of the relatively low radium and thorium content of those meteorites so far tested for natural radioactivity, little use seems to have been made of autoradiography in the study of meteorites until very recently, when it has become generally recognized that what have been called "radioactive nuclides" are produced in meteorites by exposure in a neutron pile or to the full intensity of cosmic radiation in empty space. If samples of such *activated* meteoritic material are placed in contact with or near to nuclear-emulsion plates, permanent records can be secured of the tracks in the emulsion followed by the various particles that the radioactive substances emit. From such records, valuable information can be obtained relating not only to the distribution of active material in the specimen (the so-called "topographs"), but also to the nature of the particles emitted.

Altho autoradiography with the radiations from artificial radioelements like radiophosphorus was practised before 1938,[2] the first published paper on the use of this technique to record the radiations emitted by meteorites would seem to be that of Hildegard Stücklen in *C.M.S.*, **4**, 255-8; *P. A.*, **58**, 186-9, 1950.[3]

Among the track combinations recorded by Dr. Stücklen were a considerable number of pronged configurations, which she identified as

"stars" that had resulted from an activity induced in the meteoritic specimens by their long exposure in empty space to the full intensity of cosmic radiation. This interpretation of the "stars" has recently been questioned by F. A. Paneth and his associates, who point out that the radioactive isotopes of iron and sodium tentatively assumed by Dr. Stücklen to be responsible for the pronged configurations do not emit star-producing particles.

In view of the importance of corroborating Dr. Stücklen's pioneer results, and of clearing up the debatable origin of the "stars" recorded on her plates, it is evident that such experiments as she carried out should be performed by many other investigators with the widest possible range of meteoritic specimens and under the most varied control conditions. Since the greatest possible value would attach to autoradiographic investigations of meteorites initiated within a few hours or a few days after the fall of these bodies (for, according to Dr. Stücklen, if the activity observed in some meteorites is an induced, and not a natural, activity, then its fall-off with increasing terrestrial age would be very rapid); and since the very simple techniques involved in the exposure of modern nuclear-emulsion plates can scarcely be familiar to all those students of meteoritics that may at any moment have the good fortune to recover meteorites immediately after they reach the Earth, the following brief instructions, kindly prepared for the personnel of the Institute of Meteoritics by Dr. Victor H. Regener, Professor of Physics in the University of New Mexico and one of the foremost experts on the autoradiographic study of cosmic radiation, are given, accompanied by some parenthetical comments of my own:

(1) Keep on hand and well protected in the electric refrigerator a supply of at least 2 types of Ilford Nuclear Research Plates with an emulsion thickness of 200 μ, *viz.*, the electron-insensitive type, C-2, and the electron-sensitive type, G-5. (Because of attack by ubiquitous cosmic radiation, the electron-sensitive plates deteriorate much more rapidly than the C-2 plates; for this reason, if only one type of plate is to be stocked, the insensitive plates are to be preferred.)

(2) As soon as a freshly fallen meteorite is recovered, cut and polish[4] on it a plane surface measuring at least 1 in. by 3 in., exercising extreme care to avoid leaving the finished surface contaminated by abrasive agents. (Unless the specimen to be tested is a complete, non-oriented mass, giving evidence of a more-or-less uniform ablation on all parts, separate tests should be run on surfaces cut on the *Brustseite* (front) and the rear of the meteorite, so that the effect of the greater ablation on the *Brustseite* can be determined. This precaution will be of particular importance in experiments made to test C. A. Bauer's hypothesis that the helium in meteorites has been produced by cosmic radiation.[5])

(3) Working in a photographic darkroom, place a nuclear-plate, emulsion side down, against the polished surface of the meteorite and

tape it securely in position, being careful to avoid sliding it across the meteoritic surface. (The emulsion side of the plate can be detected by slightly moistening a finger-tip and touching the very *corner* of the plate. If the finger-tip sticks slightly, it is against the emulsion.)

(4) The plate taped to the meteorite should be carefully stored away in a completely dark cabinet in the darkroom and left for from 1 to 4 weeks.

(5) Exposed plates must then be removed, processed, and, when dried, studied under a microscope for "particle-tracks" and possible "nuclear stars." (Since the processing and examination of such plates involve special techniques, which are set forth in detail in monographs on the use of nuclear-emulsion plates,[6] no attempt to discuss these topics will be made here.)

In addition to the autoradiographic method, the radioactive "nuclides" produced in meteorites thru exposure to the full force of cosmic radiation can be studied by the use of β-ray Geiger counters and similar instruments. As far as I can determine, the first such investigations of freshly fallen meteoritic material were carried out by Harrison Brown and his associates at the Institute for Nuclear Studies of the University of Chicago, between May and August, 1948. In response to requests from Dr. Brown, who planned to take ". . . long gross counts on a very thin window-counter," and, in addition, to ". . . separate a few elements that might possess sufficient activities to detect," a sample of the first fragment of nortonite (or olivine-enstatite calcium-poor achondrite, subclass = A_2eo) recovered by the Institute of Meteoritics surveys of April-May, 1948, in Norton County, Kansas, and Furnas County, Nebraska, was sent to the Institute for Nuclear Studies on May 17, 1948. On August 26, 1948, Dr. Brown reported in a personal letter to me that counts, "using a thin end-window-counter, which should have permitted most of the β's to pass, . . ." on this nortonite sample as a whole, as well as on several elements isolated from the sample, revealed no trace of radioactivity other than that attributable to the uranium, thorium, and potassium in the achondrite. Similar negative results were later obtained when a sample of nortonite was exposed "inside a very sensitive gas-filled counter," within which there was no self-absorption.

In my opinion, the negative results obtained by Dr. Brown are quite possibly due to the fact that the specimens tested by him came from positions *entirely inside* the achondritic masses (which, because of their record-breaking size, may not have been irradiated thruout their entire extent by cosmic rays). The same explanation may account for the negative results later secured by Paneth and his associates in an attempt to detect in the Beddgelert, Caernarvon, Wales, meteorite (ECN = + 0041,530; cl. = black chondrite, C(s)) radioactivities produced by cosmic radiation.[7] This meteorite, which fell on September 21, 1949, was tested with negative results by the use of a β-ray Geiger counter

on October 2, 1949 (*i.e.*, just 11 days after the fall of the meteorite). On October 4, measurements on both background and meteorite were repeated with the greatest possible precision and with the following results:

Background	12.3 ± 0.5 counts/min.
Meteorite	13.7 ± 0.3 counts/min.
Meteorite	13.7 ± 0.5 counts/min.
Background	13.7 ± 0.5 counts/min.

Paneth and his associates concluded that, 13 days after the fall of the Beddgelert meteorite, they were unable to detect any measurable β-activity in it, altho, in their opinion, cosmic rays would be much more likely to produce such a β-activity in a meteorite than an α-activity. It is not known whether a search has been made for an α-activity in the meteorite in question or whether it has been studied by the use of the autoradiographic technique employed by Dr. Stücklen on the Norton-Furnas achondrite.

References and Note

[1] Stuart H. Perry, "The Metallography of Meteoric Iron," *U. S. Nat. Mus. Bull. 184*, Washington, D. C., 1944. For a review of this important monograph, *v.* Lincoln LaPaz, *P. A.*, **53**, 99-101, 1945.

[2] C. Groven, J. Govaerts, & G. Gueben, *Nature*, **141**, 916, 1938.

[3] In a letter that Dr. Robert F. Mehl, Director of the Metals Research Laboratory of the Carnegie Institute of Technology, Pittsburgh, Pennsylvania, wrote me on March 3, 1950, he stated, "Many years ago I did some [autoradiographic] work on meteorites. I exposed Canyon Diablo meteorites to a photographic plate for many months, but I got no registration whatsoever." This testimony is of interest in connection with the results obtained by Dr. Stücklen, and their interpretation.

[4] *Cf.*, in this connection, G. L. Kehl, *The Principles of Metallographic Laboratory Practice*, 2nd Ed., New York, 1943.

[5] C. A. Bauer, *Phys. Rev.*, **72**, 354, 1947, and **74**, 225, 501, 1948.

[6] Herman Yagoda, *Radioactive Measurements with Nuclear Emulsions*, New York, 1949.

[7] K. F. Chackett, J. Golden, E. R. Mercer, F. A. Paneth, & P. Reasbeck, "The Beddgelert Meteorite," *Geochimica et Cosmochimica Acta*, **1**, 3-14, 1950.

[*To be continued*]

A Catalog of the Leonard Collection of Meteorites

Frederick C. Leonard *and* Gerald L. Rowland
Department of Astronomy, University of California, Los Angeles 24

ABSTRACT AND INTRODUCTION

Herewith is presented a summarized catalog of the Leonard Collection of Meteorites, which we have recently inventoried. This collection is housed in the senior author's office on the Los Angeles campus of the University of California.

Table 1 gives the 7-digit equatorial coördinate number, the name, the subclass, in terms of the symbols used in the simplified classification of meteorites,[1] and the combined weight, in grams, of all the specimens from each fall represented in the collection. The falls are listed alphabetically by primary name, *observed* falls being indicated by a superscript (°) preceding the name.

Each specimen (or assemblage of specimens) in the collection has glued[2] to it (or to its container, if it is too small) a round, 1-cm., specimen-label, on which are inscribed, in India ink, its class (A_1, A_2, C, S, L, H, O, or D), its equatorial coördinate number, and its serial number in the collection; and it is accompanied by a printed, 7 × 4-cm. cabinet-label, on which blanks, entitled as follows, on the various lines as numbered, are filled in, in India ink, with the information called for: (1) ECN (Equatorial Coördinate Number) and SN (Serial Number); (2) Name; (3) Subcl. (Subclass); (4) Date (of Fall, Find, or Recognition); (5) Desc. (Description); and (6) Wt. of Spec. (Weight of Specimen) and Tl. Kn. Wt. (Total Known Weight of the Fall). A complete, up-to-date manuscript catalog of the collection is kept on 5 × 3-in., ruled "index" cards.

The total number of falls represented in the collection is 166, of which 63 are observed and 103 are unobserved. The 166 falls are distributed, according to class, as follows: achondrites (A), not further classified, 1; calcium-rich or non-ferriferous achondrites (A_1), 5; calcium-poor or ferriferous achondrites (A_2), 7; chondrites (C), 88; sideraerolites (S), 5; lithosiderites (L), 6; hexahedrites (H), 9; octahedrites (O), 45; and ataxites (D), 0.

The collection contains also specimens from 3 *unidentified* falls, *to wit:* 1 piece each of 2 aerolites (AE), the pieces weighing 7.5 and 3.7 gm., respectively, and several fragments of a siderolite (SO), weighing 1.3 gm.; and it includes a 1300.0-gm. end-piece of a Mount Elden, Arizona (ECN = + 1116,353), graphitic nodule with nickel-iron veins (probably a large inclusion from a Canyon Diablo meteorite), and a small assortment of tektites (TE), consisting of 15 moldavites, weighing 86.2 gm., and 8 australites, weighing 32.5 gm., as well as a considerable quantity of oxidite (*i.e.*, terrestrially oxidized meteoritic nickel-iron—so-called "meteoritic" or "iron-shale")[3] from the falls at Canyon Diablo, Arizona, and Odessa, Texas, and a bit of the same kind of material from the fall at Willamette, Oregon.

TABLE 1. CATALOG OF THE LEONARD COLLECTION OF METEORITES

ECN	Name	Subcl.	Comb. Wt. of Sp.
+0961,387	Admire, Kansas	Lo(R)	76.8 gm.
+1059,329	Alamogordo, New Mexico	C(ck)	52.8
∓0102,456A	°Alfianello, Italy	Cho(i)	3.3
+0859,426	°Allegan, Michigan	Cho(c)	16.3
+0970,177	Apoala, Mexico	O(f)	32.2
+0991,414	Arcadia, Nebraska	A	127.7
+0943,385	°Archie, Missouri	C(g)	57.7
+1100,302	Arispe, Mexico	O(gg)	341.1
+0826,356	Asheville, North Carolina	O(m)	5.3
∓0006,431:	°Ausson, France	C(c)	9.6
+0003,440:	°Barbotan, France	C(gv)	2.0
−1446,353	Barratta, Australia	C(s)	4.8
+0982,454	°Bath, South Dakota	C(cb)	17.2
+1053,396	Bear Creek, Colorado	O(f)	129.3
+1012,398	°Beardsley, Kansas	C(g)	119.8

ECN	Name	Subcl.	Comb. Wt. of Sp.
+1036,362	Beenham, New Mexico	C(i)	69.4
—0182,254	Bethany, Southwest Africa	O(f)	41.8
+0803,342	°Bishopville, South Carolina	A_3h(v)	4.1
+0968,299A	Bluff, Texas	Cho(kb)	192.1
—1352,226	Boxhole, Australia	O(m)	217.8
∓0163,506	°Braunau, Czechoslovakia	H	11.6
+0992,376A	Brenham Tp., Kansas	Lo(K)	323.5
+0992,376A	Brenham Tp., Kansas	Lo(Kt)	153.4
+0822,366	Bristol, Tennessee	O(f)	69.5
+1055,523	Bruno, Canada	H	5.0
+0943,382	Butler, Missouri	O(ff)	105.1
+1231,409	Canyon City, California	O(m)	183.5
+1110,350	Canyon Diablo, Arizona	O(gg)	67,554.7
+1115,297	Carbo, Mexico	O(m)	385.7
+0980,319	Carlton, Texas	O(ff)	348.1
∓0080,449	°Cereseto, Italy	C(cb)	0.6
∓0017,478	°Charsonville, France	C(gv)	3.0
+0842,380:*	Clark Co., Kentucky	O(m)	35.2
+1028,287A	Coahuila, Mexico	H	106.9
+0903,449	°Colby, Wisconsin	C(iv)	16.1
∓0126,426	°Collescipoli, Italy	C(c)	0.7
+1020,380	Coolidge, Kansas	C(c)	35.9
+0832,358	Cosby's Creek, Tennessee	O(g)	20.7
+0988,392	Covert, Kansas	C(ck)	232.7
+0848,358	Crab Orchard Mtns., Tennessee	Shao	4.4
—1453,381	Cranbourne, Australia	O(g)	50.0
+0844,368	°Cumberland Falls, Kentucky	(A_2+C)e	8.8
+0953,335	Deport, Texas	O(g)	363.3
+1010,237	Descubridora, Mexico	O(m)	14.8
∓0765,322	°Dhurmsala, India	Cho(i)	4.0
+1104,402	Duchesne, Utah	O(f)	0.8
+0962,385	Elm Creek, Kansas	Cho(c)	4.8
+0839,399	Enon, Ohio	Shao	12.4
∓0074,479	°Ensisheim, France	Cho(k)	4.0
∓0065,482	°Épinal, France	C(c)	0.4
+1018,338	Estacado, Texas	Cbo(k)	55.7
+0948,434	°Estherville, Iowa	Shao	41.5
+1040,363B	Farley, New Mexico	C(k)	58.0
+0936,432	°Forest City, Iowa	Cbo(cb)	81.6
+0839,330	°Forsyth, Georgia	Cho(wv)	0.1
+1089,368	Four Corners, New Mexico	O(fan)	63.2
+1046,388	Franceville, Colorado	O(m)	79.1
+1000,400	°Furnas Co., Nebraska	A_3eo	280.3
+0952,383	Garnett, Kansas	C	71.8
—1475,303	Gilgoin Station, Australia	Cbo(k)	10.7
+1040,363A	Gladstone, New Mexico	C(ckv)	172.7
+1058,356	Glorieta Mtn., New Mexico	O(m)	290.1
+1017,393	Goodland, Kansas	C	78.3
+1205,420	Goose Lake, California	O(m-g)	8.8
+0857,430	Grand Rapids, Michigan	O(f)	12.4
+0992,398	Gretna, Kansas	C	9.7
∓0306,464	°Grossliebenthal, Ukraine	C(wv)	0.6
+1014,363	Gruver, Texas	C	206.0
+0962,438	Hardwick, Minnesota	C	279.0
+0944,387	Harrisonville, Missouri	C(gv)	353.6
—1332,246	Henbury, Australia	O(m)	2,146.3
∓0176,598:*	°Hessle, Sweden	Cbo(c)	3.8
+1100,349	°Holbrook, Arizona	C(ck)	1,050.5
+0919,418	°Homestead, Iowa	Cbo(gb)	22.3
+0966,335	Howe, Texas	C	56.9
+1033,391	Hugo, Colorado	C	12.3
+1014,372	Hugoton, Kansas	C(kb)	522.5

ECN	Name	Subcl.	Comb. Wt. of Sp.
+1086,289:	Huizopa, Mexico	O(f)	173.8
±0602,238	Imilac, Chile	Lo(I)	97.6
+0824,383	Jenny's Creek, West Virginia	O(g)	4.7
+1049,403	°Johnstown, Colorado	A_3h	50.0
∓0046,447:*	°Juvinas, France	A_1h'a	1.6
+1030,405	Kelly, Colorado	C(gb-wb)	69.3
∓0224,489	°Knyahinya, Czechoslovakia	Cho(g)	489.5
∓0930,540:	Krasnojarsk, Siberia	Lo(K)	140.1
+0855,384	La Grange, Kentucky	O(f)	60.4
∓0006,488	°L'Aigle, France	Cho(ib)	8.8
−1348,303	Lake Labyrinth, South Australia	Ceo	26.6
∓0011,478	°Lancé, France	C(rc)	1.6
+0996,399	Long Island, Kansas	Cho(iv)	123.6
+0916,420	°Marion, Iowa	Cho(wv)	2.5
+0966,332	McKinney, Texas	Cho(s)	92.9
+1036,344	Melrose, New Mexico	C	295.7
∓0220,570:B	°Misshof, Latvia	C(c)	1.4
∓0236,468	°Mocs, Rumania	Cho(wv)	191.1
−1489,333	Molong, Australia	Lo(I)	160.4
+0805,352	°Monroe, North Carolina	C(gv)	1.9
+1001,393	Morland, Kansas	C(k)	9.3
−1418,298	°Mount Brown, Australia	C(c)	11.2
+0772,398	Mount Joy, Pennsylvania	H(a)	254.1
+1178,349	Muroc, California	C	4.6
+0840,351	Murphy, North Carolina	H	6.4
+0996,385	Ness Co. (1), Kansas	C(k)	554.5
+0818,400	°New Concord, Ohio	Cho(iv)	16.2
+0763,368	Norfolk, Virginia	O(m)	100.2
+0923,362	°Norfork, Arkansas	O(m)	9.9
+1000,400	°Norton Co., Kansas-Furnas Co., Nebraska: *v.* Furnas Co., Nebraska.	A_2eo	280.3
∓0555,576	°Ochansk, Russia	C(cb)	55.0
+1025,318	Odessa, Texas	O(g)	8,229.0
+0820,500:	Osseo, Canada	O(gg)	142.6
+0992,211	°Pacula, Mexico	C(wb)	2.1
+0905,361	°Paragould, Arkansas	C(g)	8.5
∓0784,092	°Parnallee, India	C(gv)	15.1
+1038,362	°Pasamonte Ranch, New Mexico	A_1hh'a	119.0
∓0359,486	°Pavlograd, Ukraine	C(w)	3.3
+1031,301	°Peña Blanca Springs, Texas	A_2e	84.3
+0867,353	°Petersburg, Tennessee	A_1hh'a	0.7
+0988,297	Pipe Creek, Texas	C(kv)	4.3
+1016,342	Plainview, Texas	C(iv-c)	1,927.8
+1033,412	Potter, Nebraska	C(gb)	98.0
∓0211,527	°Pultusk, Poland	C(gv)	30.6
+0836,333	Putnam Co., Georgia	O(f)	7.4
+0999,386	Ransom, Kansas	C	306.9
+1023,466	°Richardton, North Dakota	C(cv)	700.3
+0774,376	°Richmond, Virginia	C(ck)	1.2
+1181,349	Rosamond Dry Lake, California	Cho	13.8
+0843,443	°Rose City, Michigan	C(sb)	26.2
+1040,359	Roy, New Mexico	C(k)	46.1
+0814,343	Ruff's Mtn., South Carolina	O(m)	116.6
+0903,378	St. Genevieve Co., Missouri	O(f)	669.3
∓0272,616	°St. Michel, Finland	C(w)	3.5
∓0046,460	°Salles, France	C(iv)	3.9
+1003,313	San Angelo, Texas	O(m)	142.3
+1067,350:*	Sandia Mtns., New Mexico	H(a)	6.0
+0982,192	Santa Apolonia, Mexico	O(m)	220.3
+0993,242	°Santa Cruz, Mexico	C(r)	20.6
+0692,443	°Searsmont, Maine	Cbo(c)	2.5

ECN	Name	Subcl.	Comb. Wt. of Sp.
+1019,337	Shallowater, Texas	$A_2h(n_e)$	22.0
+1033,395	Shaw, Colorado	A_2ho	7.2
+1037,426	°Sioux Co., Nebraska	$A_1hh'a$	5.5
+0832,340	Smithonia, Georgia	H	26.5
∓0219,436	°Soko-Banja, Yugoslavia	C(c)	3.4
+1012,362	Spearman, Texas	O(m)	52.9
+1084,520	Springwater, Canada	Lo(K)	355.1
∓0156,493	°Stannern, Czechoslovakia	$A_1h'a$	1.2
+0790,382	Staunton, Virginia	O(m)	17.6
±0702,203	Tamarugal, Chile	O(m)	337.7
+0836,364	Tazewell, Tennessee	O(ff)	161.2
∓0270,580	°Tennasilm, Estonia	C(cv)	1.5
∓0352,548:	°Timochin, Russia	C(c)	0.4
—1114,068:A	°Tjabé, Java	C(k)	4.0
+0882,322	Tombigbee River, Alabama	H(a)	136.6
+0736,429	Tomhannock Creek, New York	C(gb)	1.1
+0882,434	Trenton, Wisconsin	O(m)	132.2
∓0102,456B	°Trenzano, Italy	C(cv)	1.5
+1018,345	Tulia, Texas	C(kv)	217.1
+1012,376	Ulysses, Kansas	C	2.3
±0690,260:	Vaca Muerta, Chile	Shao	32.1
∓0003,466A	°Vouillé, France	C(iv)	2.3
+0912,388	°Warrenton, Missouri	Cho(c)	1.5
+1039,403	Weldona, Colorado	C(ck)	90.6
+0734,412	°Weston, Connecticut	C(cb)	5.3
+1227,454	Willamette, Oregon	O(m)	389.2
+1114,352	Winona, Arizona	Shao	123.6
+0997,194	Xiquipilco, Mexico	O(m)	1,309.1
+0970,177	Yanhuitlan, Mexico	O(f)	3.8
—1178,319	Youndegin, Western Australia	O(g)	19.4
+1025,228	Zacatecas, Mexico	H(a)	50.6

References and Note

[1] *C.M.S.*, **5**; *P.A.*, **59**, 370-7, Aug., 1951.

[2] By means of "Ambroid Liquid Cement" (manufactured by the Ambroid Co., Inc., Boston), which can be thinned, if necessary, with C.P. acetone. Acetone can be employed likewise for removing *painted* labels from specimens.

[3] *C.M.S.*, **5**, 46-7; *P.A.*, **59**, 212-13, 1951.

1951 August 29

ADDENDUM

The following 3 specimens have been added to the collection since the foregoing catalog was compiled, thus bringing the total number of represented falls to 169, of which 106 are unobserved and of which 47 are octahedrites (O) and 1 is a plessite ataxite (Dp); moreover, 303.8 gm. of small Canyon Diablo irons (cl. = O) have been added, thus bringing the combined weight of the specimens from that fall to 67,858.5 gm.

ECN	Name	Subcl.	Comb. Wt. of Sp.
+1083,353	Breece, New Mexico	O(m)	39.1 gm.
+1137,354:	Wallapai Indian Reservation, Arizona	O(f)	21.0
+1126,340	Weaver Mtns., near Wickenburg, Arizona	Dp	24.6

1951 September 19

A Very Bright Fireball with an Enduring and Drifting Train*

On 1950 December 15, at about $22^h\,00^m$ U.T., a swift fireball, much brighter than the —6th magnitude, covered a track 25° long in a couple of seconds, from a point whose coördinates were azimuth (A) = 134°, altitude (h) = 42½°, to a point whose coördinates were $A = 103°$, $h = 34°$, the midpoint of the track having the coördinates $A = 118½°$, $h = 40°$. The shape of the train became sinuous after 4 or 5 minutes, and the train was most concave southward at the midpoint. This part drifted to within 4½° of the star 21 Lyncis—*i.e.*, to a point whose coördinates were $A = 115°$, $h = 50½°$, in 15 minutes. An afterglow continued to spread mostly towards the north and a little towards the east. Unlike former long-enduring trains that I have observed, this one did *not* become "hollow" at the axis with lapse of time; that is, the axial portion also continued to be visible all the time until the intensity of the afterglow dwindled to naught at $22^h\,20^m$ U.T. No hissing sounds and no explosion were heard. MOHD. A. R. KHAN

Begumpet, Deccan, India, 1951 April 24

*Read at the 14th Meeting of the Society, Los Angeles, California, 1951 June 18-19.

Secretary's Notices

Council Vacancy Filled.—Under date of 1951 September 25, Mr. D. Moreau Barringer, of the Standard Iron Company, 1528 Walnut St., Philadelphia 2, Pennsylvania, was appointed by the Council of the Society to fill the vacancy among the Councilors caused by the death of Dr. Curvin H. Gingrich, of Goodsell Observatory, Carleton College, Northfield, Minnesota, on 1951 June 17.

Fellows Elected.—As of date 1951 September 25, the following 2 members were elected to fellowship in the Society by the Council:

Dr. Herbert H. Uhlig, 8-202 Massachusetts Institute of Technology, Cambridge 39, Massachusetts; and

Professor W. A. Wahl, 1 Kyrkogatan, Helsingfors, Finland.

The 15th Meeting of the Society.—The Council of the Society has accepted an invitation from the Institute of Meteoritics of the University of New Mexico, Albuquerque, to hold the 15th Meeting of the Society at the Institute on September 2, 3, and 4, 1952. The Institute anticipates the completion and dedication of its new quarters in the projected Physics and Meteoritics Building of the University of New Mexico at that time. JOHN A. RUSSELL, *Secretary*

Erratum in the May, 1951, Issue.—P. 265, Table 1, column (2), first datum, "20.78%," should read, "80.78%."

President of the Society: L. F. BRADY, 922½ Forest Avenue, Tempe, Arizona
Secretary of the Society: JOHN A. RUSSELL, Department of Astronomy, University of Southern California, Los Angeles 7, California

The Planets in December, 1951

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time, unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac.*

Sun. The date of the Winter Solstice, when the sun stands 23½ degrees south of the equator, will be December 22 at 10 A.M. During most of the month, the sun will be within a degree of this extreme southern declination.

Moon. The phases of the moon will occur as follows:

First Quarter	December 5	10 A.M.
Full Moon	13	4 A.M.
Last Quarter	21	9 A.M.
New Moon	28	6 A.M.

The moon will be at perigee on December 28.

Evening and Morning Stars. Jupiter will be near the meridian at sunset, while Saturn, Mars, and Venus will be visible in the eastern morning sky.

Mercury. Since it will pass inferior conjunction with the sun on December 16, Mercury will be practically invisible during this month.

Venus. After its rising at about 4 A.M., Venus will be the most conspicuous object in the morning sky.

Mars. Mars will be rising at about 2 A.M. It is still moving rapidly eastward, and on December 19 at 7 A.M. it will catch up with and pass only half a degree south of Saturn. Also, its brightness will be rapidly increasing so that it will be only slightly fainter than Saturn, but the red color of Mars should easily distinguish it.

Jupiter. Jupiter will remain the most conspicuous object in the evening sky, and most favorably situated for early evening observation.

Saturn. Since it will be rising at about 2 A.M., Saturn will be well-placed for observation just before dawn. Its close association with Mars, culminating in a conjunction on December 19, is described under the latter planet.

Uranus. Uranus will be moving slowly westward at about midway between ϵ and ζ Geminorum.

Neptune. Neptune will be moving east-southeastward some 4 degrees north of Spica.

Department of Mathematics, University of Louisville, Louisville, Kentucky,
October 1, 1951.

Asteroid Notes

By HUGH S. RICE

We are giving ephemerides of the brightest minor planets available at this time, those with magnitudes 8 to 10.

79 EURONYME is of magnitude 9.3 and comes to opposition October 26. It is found at the Aries-Pisces boundary, passing south of Alpha Piscium. 356 LIGURIA is of magnitude 9.7 and comes to opposition October 28. It is in western Aries, passing only about ¼° north of Alpha Arietis on November 1. 22 KALLIOPE, of magnitude 9.3, is at opposition November 8, and is in Cetus, north of Alpha Ceti. 11 PARTHENOPE, of magnitude 9.2, is at opposition November 13, and is at the Taurus-Aries-Cetus boundary. 386 SIEGENA, of magnitude 9.7, is at opposition November 22, in Eridanus. 15 EUNOMIA has a magnitude of 8.0 at opposition November 28; it is at the Gemini-Auriga border.

ASTEROID EPHEMERIDES

0^h U.T. Equinox 1950

79 EURYNOME

1951	α h m	δ ° ′
Oct. 11	2 12.9	+13 32
21	2 5.7	+12 15
31	1 57.4	+10 53
Nov. 10	1 50.3	+ 9 35
20	1 45.0	+ 8 34

356 LIGURIA

1951	α h m	δ ° ′
Oct. 1	2 29.9	+22 23
11	2 24.6	+23 6
21	2 16.2	+23 28
31	2 6.2	+23 30
Nov. 10	1 56.2	+23 16
20	1 47.8	+22 53

22 KALLIOPE

1951	α h m	δ ° ′
Oct. 11	3 16.6	+ 7 30
21	3 9.9	+ 7 30
31	3 1.1	+ 7 32
Nov. 10	2 51.4	+ 7 39
20	2 41.9	+ 7 55
30	2 33.7	+ 8 23

11 PARTHENOPE

1951	α h m	δ ° ′
Oct. 21	3 31.1	+11 19
31	3 22.7	+10 39
Nov. 10	3 13.0	+10 1
20	3 3.2	+ 9 30
30	2 54.5	+ 9 11
Dec. 10	2 48.1	+ 9 7

386 SIEGENA

1951	α h m	δ ° ′
Oct. 31	4 5.2	− 8 38
Nov. 10	3 58.6	−10 10
20	3 50.9	−11 15
30	3 42.9	−11 46
Dec. 10	3 36.1	−11 41
20	3 31.2	−11 6

15 EUNOMIA

1951-2	α h m	δ ° ′
Nov. 30	6 53.3	+31 24
Dec. 10	6 44.7	+30 59
20	6 33.7	+30 22
30	6 22.0	+29 34
Jan. 9	6 11.0	+28 37
19	6 2.2	+27 33

Hayden Planetarium, American Museum of Natural History, New York, 1951 October 10.

Occultation Predictions for December, 1951

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from

the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Date 1951	Star	Mag.	IMMERSION Greenwich C.T. h m	*a* m	*b* m	Angle E from N °	EMERSION Greenwich C.T. h m	*a* m	*b* m	Angle E from N °
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
Dec. 2	36 B.Capr	6.2	21 54.2	—1.2	+0.2	54	23 3.8	—1.1	—0.5	249
16	κ Gemi	3.7	1 1.1	+0.6	+2.8	48	1 44.4	—1.0	—0.6	323
25	CD—23°12133	6.4	11 18.1	—0.4	—0.4	146	12 20.6	—1.8	+0.7	269
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
Dec. 2	36 B.Capr	6.2	21 29.9	—1.2	+1.3	30	22 35.0	—2.2	—0.5	275
Occultations Visible in Longitude +120° 0′, Latitude + 36° 0′										
Dec. 16	5 B.Canc	6.4	10 15.9	..	..	56	11 2.7	..	..	356
16	9 Canc	6.2	14 9.4	—0.5	—2.1	127	15 15.4	—0.3	—1.6	288
22	χ Virg	4.8	12 43.0	—2.4	+1.0	88	13 40.6	—0.2	—2.5	354

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The following notes will give the data, so far received, for rates on the meteors observed during July and August, 1951. As will be seen, a truly impressive amount of work was done. Here only some general remarks will be made, leaving to a later article a more comprehensive study of the summer rates, observed in North America by our members and helpers. This is the more desirable as undoubtedly more results will be reported by some who have been slower in sending them in. Also there will undoubtedly be a large number of radiants upon the scores of maps which have been submitted, and to properly deduce these is a matter which takes much time and trouble. But I wish to reassure the persons who spent so much time in this work that their maps will have the proper attention so soon as time permits.

I wish to call especial attention to the several observers, listed in our table, who managed to observe on so many nights during the interval covered, and what is of even more importance so often put in several hours of observing on a given night. It further happens that, in several parts of the country, such work was done on the same night. This will give us one of the best opportunities we have had for a really scientific study of the rates on other nights than those of the actual shower maxima. Further, several of the observers have now had so much practice and done so much observing that their work becomes increasingly valuable, and we can have far more confidence in the radiants that will be deduced from their maps. While it is almost invidious to mention names when so many have contributed excellent work, yet special attention should be called to two of our members who have been doing a very great amount of observing. The first is Arthur Pearlmutter of Forest Hills, Long Island, N. Y., who during 1951 up to the end of August had observed 2922 meteors, practically every one plotted.

His work is further a model of neatness, with necessary information recorded on the blanks in the proper places. In Portland, Oregon, Richard Widner, who began his 1951 work in early July, observed 605 meteors during July and August. His maps and records leave nothing to be desired in completeness and clearness. The work of the Missouri group, now by far our most active, is represented here by that of Tom Adams, Walter Houston, and James Jekel. This group has already on several occasions received most favorable comment in these notes and what these observers did this summer will add to their reputation. There is reason to believe that a good deal of work, done by others of this group, is not yet reported to us. We wish further to express our appreciation to two ladies, not formal A.M.S. members, who have for several years submitted valuable meteor rates: Miss Alice K. Jensen of Silverton, Oregon, and Miss Eleanor Sandmeyer of Buhl, Idaho. The latter also interested some others near her to make counts at the Perseid maximum.

The writer did not send out any general request for counts by casual observers this past August, so very few indeed of such persons did anything that we know of. Also many of our observers in the Eastern United States, ready and willing to work near the Perseid maximum, had no chance to do anything really useful due to a wretched spell of cloudy or hazy weather which prevailed in early August. But when we allow for all the bad luck due to clouds we still are faced with the unpleasant fact that over three-fourths of our nominal membership did not report a single meteor. Nor did they work regularly on any nights, during the past summer. I hasten to add that some whose names do not occur in the accompanying table reported good work done in June and September. Neither month is covered there. But many simply never do anything! Why they joined the A.M.S. is a mystery when they take no least part in our activities. So long as such persons pay their dues we keep them on the membership list as we hope that sooner or later they will come to life, but in many cases such hope seems vain. But fortunately those who do work really contribute much to the advancement of meteoric astronomy.

Perhaps a word should be added to reassure persons who have heard of the wonderful discoveries expected from the new Schmidt meteor cameras and the use of radar. Both of these will bring results of great accuracy and importance, but to complement and interpret their results, so that they can be made most valuable, the work of the visual observer is and will continue to be needed for decades to come. Hence our members need not fear that what they are doing is becoming of small importance and will be superseded wholly by the newer methods and instruments. I can assure them that such is not the case. Further, in becoming a good meteor observer one gets excellent training in making observations which stand him in good stead if he undertakes any other sort of scientific work. A good many of our former members also, who joined when quite young—usually when in high school—now hold important professional positions in observatories or laboratories. I am sure none of them regret the training plotting meteors gave them. Lastly, to many of us there is a real fascination in the work: one has to learn the constellations well so that they become really familiar (and many professional astronomers know them scarcely at all) and one never knows when some specially interesting meteor will flash into view, or even occasionally a beautiful fireball may appear or a long-enduring train may be left. So in view of the above facts, I have no hesitation in urging our members to continue their good work indefinitely.

The maxima of both the Orionids and the Geminids will be seriously troubled

by moonlight, but during almost any night from now up to mid-December, when the sky is clear and the Moon absent, a fair number of meteors may be seen per hour by an observer in a favorable station. For those who are able to put in a few part nights per month, work on meteors during the next three months should be worth while on nearly any date. Minor streams are always in activity and we are anxious to determine with more certainty which of these have real existence and may be counted on for annual returns. At present, such information is most scanty.

In our table most of the headings are self-evident, but something should be said about F, the factor for night. 1.0 means perfect transparency, no moonlight; for the former with a full Moon we cut it down to at least 0.4. Observers try to estimate what proportion of meteors are lost due to haze, lights, passing clouds, moonlight, etc. In some cases they do not give F themselves nor enough information for me to make an estimate; in others their notes show their estimated F is certainly wrong and I do not hesitate to change it. The rates are uncorrected; to correct divide by F. The last column, headed by C, shows whether the meteors were (in general) plotted P, described D, or only counted C. Rates cannot be derived for counts by groups, at least in such a way as to be comparable with those for a single observer. With regard to rates, it is evident that those who count only must, under given conditions, see more meteors per hour than those who plot. Hoffmeister has developed a formula to take care of this, for his own case. When I was in good practice, I used to take 40 seconds to make a complete record and plot a meteor, on an average. For observers out of practice anywhere from 1 to 5 minutes may be taken. For most observers in this table somewhere between 40 and 60 seconds should be about right. However, until a fuller study is made, the point need not be settled here individually, but I wished to mention it because those who plotted so many on or near the shower maxima would need their rates greatly increased to compare them fairly with those who counted only, or who plotted but few.

TABLE I

Observer, Station, Time	Date 1951	Began	Ended	Min.	Met.	F	Rate	Obs.	C
Kirkwood, Mo.—C.S.T.									
Adams, Tom	7 4	9:50	10:40	50	7	0.9	8	1	P
" "	19	9:35	10:35	60	7	0.7	7	1	P
" "	25	9:00	11:00	120	18	0.7	9	1	P
" "	26	9:45	10:45	60	6	0.6	6	1	P
" "	30	8:55	11:00	125	17	0.5	8	1	P
" "	8 1	10:00	14:45	285	100	1.0	21	1	P
" "	6	8:45	13:45	300	78	0.9	16	1	P
" "	11	11:05	16:00	260	157	0.9	36	1	PD
" "	22	8:45	10:15	90	22	1.0	15	1	P
" "	24	9:05	9:50	45	10	0.8	13	1	P
" "	29	9:30	11:15	105	25	0.9	14	1	P
" "	31	11:45	12:30	45	11	0.9	15	1	P
Rush City, Minn.—C.S.T.									
Anderson, R. F.	8 11	10:00	14:05	155	39	0.6	16	1	CP
" "	18	10:00	12:00	120	10	1.0	5	1	C
Wilson, N. C.									
Bissette, Billy	7 11	10:45	13:30	165	10		4	1	P
" "	12	10:30	12:00	90	6		4	1	P
" "	23	9:45	10:45	60	5		5	1	P
" "	26	11:07	13:05	118	8		4	1	P
" "	27	11:03	13:30	147	10		4	1	P
" "	31	9:11	12:20	189	29		9	1	P

Observer, Station, Time	Date 1951	Began	Ended	Min.	Met.	F	Rate	Obs.	C
Grant's Pass, Ore.									
Bones, B. R.	8 10	14:00	15:00	60	55		55	1	C
Buhl, Idaho									
Brannen, Mrs. Don	8 11	14:10	14:45	35	25		..	2	C
Tucson, Ariz.—M.S.T.									
Burlinson, M. A.	8 11	14:00	15:00	60	24	0.7	24	1	C
Burlinson, Mrs. L. O.	8 11	14:00	15:00	60	21	0.7	21	1	C
Eugene, Ore.									
Coffin, Ruth	8 11	16:00	17:00	60	41	0.8	41	1	C
Cape Elizabeth, Me.—E.S.T.									
Dole, R. M.	8 13	13:30	14:30	60	20	1.0	20	1	P
Salem, Ore.—P.S.T.									
Graham, J. W.	8 12	10:30	12:00	90	67	...	44	1	C
Scotch Plains, N. J.—E.S.T.									
Griswold, D. E.	8 1	13:19	14:31	72	36	0.8	30	1	D
St. Charles, Mo.—C.S.T.									
Houston, Walter	7 1	9:05	10:05	60	2	1.0	2	1	P
" "	2	10:10	11:10	60	8	1.0	8	1	P
" "	6	12:20	13:20	60	8	1.0	8	1	P
" "	7	9:15	11:00	105	10	1.0	6	1	P
" "	10	10:00	11:00	60	8	1.0	8	1	P
" "	15	9:45	10:45	60	5	0.8	5	1	P
" "	17	10:30	11:30	60	1	0.5	1	1	P
" "	29	10:15	13:15	180	17	0.9	6	1	P
" "	8 3	9:50	10:50	60	5	0.9	5	1	P
Webster Groves, Mo.—C.S.T.									
Houston, Walter	8 11	11:11	15:25	215	39	1.0	11	1	P
Pacific, Mo.—C.S.T.									
Jekel, James	7 4	10:00	10:40	40	5	0.9	8	1	P
Indianapolis, Ind.									
Jekel, James	7	9:25	10:25	60	9		9	1	P
" "	(a)	9:00	11:00	120	16		8	1	P
Pacific, Mo.									
Jekel, James	26	9:40	13:55	255	52	1.0	12	1	P
" "	29	10:45	15:36	291	79	0.8	16	1	P
" "	8 2	9:30	11:30	120	24	0.7	12	1	P
" "	3	10:45	14:15	210	83	1.0	24	1	P
" "	11	11:05	16:00	250	161	1.0	39	1	P
Kirkwood, Mo.									
Jekel, James	21	9:35	10:20	45	10	0.7	13	1	P
" "	24	10:20	11:20	60	10	0.8	10	1	P
" "	30	8:50	11:00	120	32	1.0	16	1	P
" "	31	9:30	10:30	60	17	1.0	17	1	P
Silverton, Ore.—P.S.T.									
Jensen, Alice K.	7 28	10:10	11:40	90	31	0.8	21	1	C
" "	29	10:10	11:10	60	19	0.8	19	1	C
" "	30	10:03	11:03	60	20	0.8	20	1	C
" "	31	9:23	10:23	60	18	0.8	18	1	C
" "	8 8	12:15	13:15	60	27	0.8	27	1	C
" "	9	12:44	13:44	60	22	0.8	22	1	C
" "	11	13:44	14:34	50	45	0.6	54	1	C
" "	12	12:40	13:40	60	51	0.8	51	1	C
" "	12	13:40	14:40	60	64	0.8	64	1	C
" "	12	14:40	15:10	30	34	0.8	68	1	C
" "	13	14:15	15:15	60	49	0.8	49	1	C
San Francisco, Calif.—P.S.T. (b)									
Malville, Kim	7 25	9:15	11:15	120	31	0.9	16	1	C
" "	24	10:30	11:15	45	7	0.9	10	1	C
" "	27	9:15	11:15	120	29	0.9	14	1	C
" "	30	12:12	14:12	120	66	0.9	33	1	C
" "	8 11	11:45	15:45	240	240	0.9	60	1	D

Observer, Station, Time	Date 1951		Began	Ended	Min.	Met.	F	Rate	Obs.	C
Forest Hills, L. I., N. Y.—E.S.T.										
Pearlmutter, Arthur	7	1	9:25	14:25	300	46	...	9	1	P
" "		2	9:17	12:15	178	54	0.7	18	1	P
" "		3	9:01	13:12	251	44	0.7	11	1	P
" "		5	11:25	13:45	140	42	0.9	18	1	P
" "		6	10:55	15:00	245	71	0.9	17	1	P
" "		7	9:30	15:00	330	121	0.9	22	1	P
" "		8	10:00	15:00	300	107	0.8	21	1	P
" "		9	9:33	14:15	282	77	0.8	16	1	P
" "		10	9:17	13:10	...	16	...	..	1	P
" "		14	9:20	14:30	310	46	0.8	9	1	P
" "		15	9:37	12:30	173	22	0.6	8	1	P
" "		20	8:47	13:40	293	39	0.9	8	1	P
" "		24	9:00	14:23	323	46	0.7	9	1	P
" "		25	9:17	15:35	378	88	0.7	14	1	P
" "		26	9:35	15:55	380	156	0.7	25	1	P
" "		30	8:28	15:30	422	133	0.5	19	1	P
" "	8	1	8:40	15:50	430	192	0.9	27	1	P
" "		2	9:10	15:25	375	135	1.0	22	1	P
" "		3	9:37	14:30	293	157	0.9	32	1	P
" "		6	8:37	9:30	53	11	...	12	1	P
" "		17	10:31	12:40	129	36	0.6	17	1	P
" "		18	10:14	15:00	286	106	0.8	22	1	P
" "		22	9:56	11:34	98	31	0.7	19	1	P
" "		23	10:29	11:00	31	10	0.7	20	1	P
" "		25	9:54	12:00	126	24	0.8	11	1	P
Buhl, Idaho										
Sandmeyer, Eleanor	8	9	15:20	15:45	25	6	1.0	14	1	C
" "		10	14:00	15:30	90	38	1.0	25	1	C
" "		11	14:25	15:25	60	49	1.0	49	1	C
Sandmeyer, Isabel	8	10	14:00	15:30	90	32	1.0	21	1	C
" "		11	14:25	15:25	60	47	1.0	47	1	C
Yerkes Observatory, Wis.—E.S.T.										
Schulte, Dan	8	11	11:30	13:00	90	21	0.9	14	1	P
Chicago, Ill.—C.S.T.										
Singer, Burton	8	10	13:30	15:31	121	26	1.0	13	1	P
" "		11	12:53	13:53	60	36	1.0	36	1	P
Wilmington, N. C.										
Strayhorn, Donald	7	9	10:00	11:45	105	4		2	1	P
" "		11	11:45	13:30	105	15	0.9	9	1	P
" "		12	10:30	12:00	90	5	0.4	3	1	P
" "		22	8:50	10:15	85	5		4	1	P
" "		23	9:45	10:45	60	7	0.7	7	1	P
" "		26	11:00	13:00	120	10		5	1	P
" "		27	11:00	12:30	90	12		8	1	P
Wilson, N. C.										
Strayhorn, Donald	7	31	9:11	11:20	129	25	1.0	12	1	P
Wilmington, N. C.										
Furches, W. H.	7	9	10:00	11:45	105	9		5	1	C
Ames, Iowa—C.S.T.										
Winkel, Dave	8	10	12:00	13:00	60	71	1.0	..	6?	C
" "			13:00	14:00	60	80	1.0	..	6?	C
" "		11	12:30	13:30	60	130	1.0	..	6?	C
" "			13:30	14:24	54	135	0.7	..	6?	C
Birmingham, John	8	11	12:30	14:00	90	19	0.7	13	1	P
Dykater, J. D.	8	10	12:00	14:00	120	17	1.0	8	1	P
" "			12:30	14:00	90	19	0.7	13	1	P
Koends, J. F.	8	10	12:00	15:30	210	21	1.0	6	1	P
" "		11	13:00	14:00	60	12	0.7	12	1	P
" "		11	12:30	14:00	90	17	0.7	11	1	P
Ginter, Ellen	8	10	12:00	13:40	100	17	1.0	10	1	P

Observer, Station, Time	Date 1951	Began	Ended	Min.	Met.	F	Rate	Obs.	C
Ames, Iowa—C.S.T.									
Key, O.	8 10	11:45	14:00	135	9	1.0	4	1	P
" "	11	11:45	14:30	165	14	0.7	5	1	P
Winkel, Dave	8 11	12:30	14:20	110	13	0.7	7	1	P
Portland, Ore.—P.S.T.									
Widner, Richard	7 8	11:00	12:05	65	5	0.8	5	1	P
" "	10	11:19	13:24	125	22	0.7	11	1	P
" "	11	11:52	12:52	60	12	0.6	12	1	P
" "	13	10:37	12:22	105	17	0.5	10	1	P
" "	29	11:40	15:00	200	52	0.7	16	1	P
" "	30	11:05	13:05	120	22	0.7	11	1	P
" "	31	11:30	13:30	120	24	0.7	12	1	P
" "	8 1	11:25	13:50	145	23	0.6	10	1	P
" "	2	11:55	14:25	150	37	0.8	15	1	P
" "	4	12:20	14:40	140	26	0.8	11	1	P
" "	5	11:00	12:30	90	18	0.7	12	1	P
" "	7	12:01	13:46	105	24	0.6	14	1	P
" "	9	12:40	13:25	45	18	0.7	24	1	P
" "	11	11:15	15:05	230	103	0.8	27	1	P
" "	13	11:40	13:45	125	42	0.6	20	1	P
" "	14	10:50	12:50	120	25	0.4	12	1	P
" "	22	10:25	11:40	75	16	0.7	13	1	P
" "	23	10:15	11:30	75	14	0.5	13	1	P
Otumwa, Iowa									
Worley, C. E.	7 1	10:30	15:00	270	572	0.8	12	1	P
" "	3	10:50	15:05	255	67	1.0	16	1	P
" "	4	10:30	11:50	80	16	1.0	12	1	P
Reports, miscellaneous or incomplete	Aug.			...	77		..	10	

NOTES: (a) Date omitted on record but after July 9.
(b) Dates possibly transposed.

In closing, may I ask that persons try to report more promptly, especially those who do not have long lists to make up. And also extend a cordial invitation to persons who are not now in the American Meteor Society and who have some real interest in meteoric astronomy to write us with a view to joining.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pa.
1951 September 27.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By MARGARET W. MAYALL, Recorder

Light Curves of Ten Semi-Regular Red Variables. The last ten years (1941-1951) of A.A.V.S.O. observations for ten of the semi-regular red variables are shown on the accompanying chart. They all have the same general characteristics in their light curves: at times they are nearly constant in light and at other times their variations seem almost periodic. Their spectra are of type M, and most of them show no emission lines. Their range of magnitude is about the same, and most of them vary around the 10th magnitude.

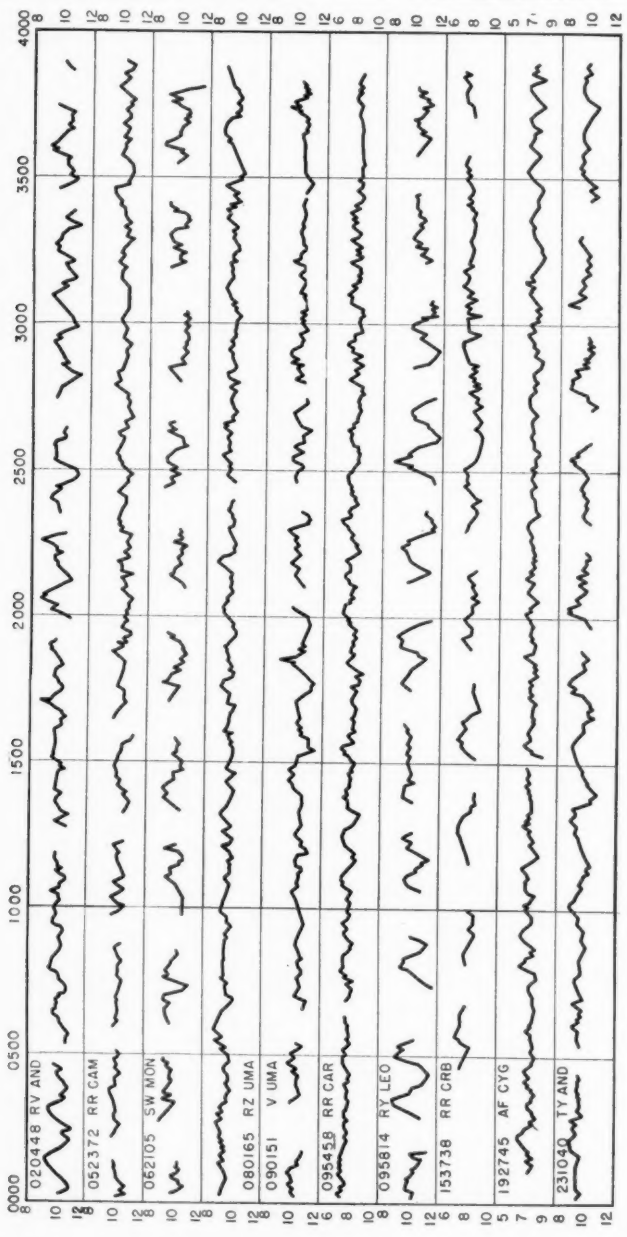

0000
0500
1000
1500
2000
2500
3000
3500
4000
020448 RV AND
052372 RR CAM
062105 SW MON
080165 RZ UMA
090151 V UMA
095458 RR CAR
095814 RY LEO
153738 RR CRB
192745 AF CYG
231040 TY AND

Table I lists the variables with information about magnitude, period, and spectra, as given in the "General Catalogue of Variable Stars," by Kukarkin and Parenago, 1948. The maximum and minimum magnitudes given in the catalogue are the extreme published values. The range given in the catalogue is usually greater than we find from our 10-day mean light curves. There are at least a dozen more such variables on the A.A.V.S.O. observing list.

TABLE I

Variable		Max.	Min.	Per.	Spec.
020448	RV And	8.3	11.5	167	M4e
052372	RR Cam	9.6	11.3	124	M6
062105	SW Mon	9.2	10.6	112	M5
080165	RZ UMa	8.9	10.2	?	M6
090151	V UMa	9.6	11.0	210	M5
0954*58*	RR Car	*9.1*	*10.4*	109	M6
095814	RY Leo	9.0	11.7	155	M2e
153738	RR CrB	7.1	8.6	60	M5
192745	AF Cyg	*7.4*	*9.4*	94	M6
231040	TY And	7.9	10.3	135	M6e

The mean light curve of 0954*58* RR Carinae is very similar to the curve of 115158 Z Ursae Majoris, which was reproduced in these Notes in POPULAR ASTRONOMY, **58**, page 307, June, 1950. It has long periods of nearly constant light at approximately median brightness.

095814 *RY Leonis* has a greater range than the others of the group, and many times it appears to be an ordinary long-period variable. But three times during the 4,000-day interval shown in the curve, the periodicity breaks down, and the variation is either irregular or almost constant.

192745 *AF Cygni* has been particularly interesting during the 1,000-day interval from 1949 to the present time. During the last 500 days, the light curve has been very similar to 1842*05* R Scuti, and maxima have been observed less than 100 days apart.

195656 *RR Telescopii.* Several studies of the spectrum of RR Telescopii have been published during the last year. In the *Monthly Notices of the Royal Astronomical Society* (**100**, 46, 1950), Dr. A. D. Thackeray discussed the changes that took place between June and September, 1949. It changed from a class F spectrum with absorption lines to an emission-line spectrum of hydrogen and Fe II.

In September, 1950, Dr. K. G. Henize obtained some infra-red spectra at the Lamont-Hussey Observatory in South Africa. He and Dr. D. B. McLaughlin report on their studies in *The Astrophysical Journal* (**114**, 163, 1951). They conclude that the star probably belongs to the group of slow novae, similar to RT Serpentis. But it is still a question as to whether or not RR Telescopii is a double star, one component of which was the nova and the other a long-period variable. The increase in amplitude of the long-period variable before the great outburst (M. W. Mayall, *H. B.*, **919**, 15, 1949) seems to indicate that something took place within the long-period variable.

Observations Received during September, 1951. A total of 5,105 observations was received during the month from the following 68 observers:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Adams, R. M.	61	213	Kelly, F. J.	10	10
Ahnert, P.	23	65	Kirchhoff, P.	19	26
Ancarani, M.	31	52	Knowles, J.	12	79
Armfield, L. E.	8	14	de Kock, R. P.	135	551
Bicknell, R. H.	21	212	Leutenegger, E.	15	28
Bogard, D.	46	90	Lowder, W. M.	9	13
Boutell, H. G.	9	42	Luft, H.	6	30
Cain, C. V.	3	4	Melville, E. C.	14	48
Charles, D. F.	17	25	Miller, W. A.	48	65
Costello, R. B.	14	15	Morrisby, A. G. F.	34	104
Cragg, T.	20	20	Motley, G.	43	64
Dafter, R.	6	18	Oravec, E. G.	66	170
Darling, B.	35	107	Parker, P. O.	38	38
Darnell, P.	1	4	Pearcy, R. E.	24	25
Darsenius, G.	19	48	Peltier, L. C.	60	264
Diedrich, DeL.	3	3	Peter, H.	33	378
Diedrich, G.	7	16	Pohl, E.	23	130
Domke, K.	28	274	Reeves, W. P.	2	4
Fernald, C. F.	163	251	Renner, C. J.	198	218
Fernald, E. S.	4	6	Richter, G.	6	21
Ficonetti, R.	20	25	Rosebrugh, D. W.	24	226
Ford, C. B.	30	31	Schulte, D.	8	10
Galbraith, W. H.	52	136	Segers, C.	20	41
Goodsell, J. G.	2	2	Sherman, R. L.	11	27
Greenley, R. M.	79	139	Singer, B.	3	48
Hales, W. LaV.	2	6	Snow, D.	4	4
Halvorson, D. O.	12	26	Sofronijewitsch, D.	17	100
Hamilton, R. W.	3	5	Stevens, W. A.	25	65
Hartmann, F.	128	135	Taboada, D.	21	21
Herring, A. K.	12	12	Tarbell, E. D.	4	7
Hiett, L.	15	28	Tarwater, C.	20	34
Holloway, J. L.	13	17	Venter, S. G.	28	43
Houston, W.	8	14	Weber, J. A.	9	9
Jahn, A.	12	115	—		—
Jerabek, H. S.	14	34	68	Totals	5105

Nova Search. Nova Search reports were received during September from 8 observers, as follows:

Observer	Area	No. Nights	Mag.	Observer	Area	No. Nights	Mag.
Adams, R. M.	16, 17, 39, 40, 57, 58, 86, 87	7	8	Rick, L.	Dome	3	2
					Dome	6	1
Darsenius, G.	Dome	1	1		18	3	5
	16	7	5		18	6	4
	16	1	4		63	4	5
	17	1	2		63	5	4
Diedrich, DeL.	40	1	6	Rosebrugh, D. W.			
	40	2	5		Dome	9	3
Diedrich, G.	Dome	4	2		Dome	1	2
	78	2	6		1	4	4
	78	2	5		34	1	4
	78	1	4	Smith, F. W.	3, 4	8	6
Luft, H.	28, 29, 30	5	5				

October 5, 1951.

Comet Notes

By G. VAN BIESBROECK

There are no known comets in reach of small or even median-sized telescopes at this time. The latest discovered one 1951 *i* (Wilson-Harrington) is now approaching the sun and being lost in the evening sky. It will be seen again early next year when it will be much brighter than at discovery.

In his Halley lecture at the Royal Astronomical Society in Oxford last May, J. H. Oort, Director of the Leiden Observatory (Netherlands), made an interesting synthesis of our present knowledge about comets and came to some novel conclusions concerning their origin and development. What causes their strange appearance, the changes in their coma and their often very long tails? Drawing upon plausible assumptions about the reflectivity of the nucleus results in the belief that that its diameter must be less than a very few miles. It has therefore too small a mass to keep gas or dust particles together. The head of the comet is formed by particles escaping from the small solid nucleus. These particles move out more or less continuously and stay only a couple of days in the coma. The source of the particles is the solid nucleus itself, which is too small to be distinguished visually but constitutes the essential permanent part of the comet. In some cases the material ejected from the nucleus stretches out in the most spectacular feature of the comet, namely its tail. Long streamers in these are very likely related to the local jets through which the material escapes from the rotating solid nucleus. Radiation pressure explains why the tails are pushed away from the sun but other forces, probably electromagnetic, must be acting simultaneously to account for the high velocities and accelerations observed in the tail material and for the presence of strongly diverging rays.

In the lecturer's opinion comets originate from material which is part of the original solar system but situated at enormous distances beyond the planetary orbits. From statistical considerations, he estimates that the solar system is surrounded by a vast spherical tenuous mass containing some 100 billion comets. Since their individual masses are small, the total mass of this cloud of material need not be larger than one tenth of that of the earth—they are at such distances that stellar perturbations modify their velocity distribution so that some are lost in interstellar space while a small per cent can come in the inner regions of the solar system and then become visible as "new comets." Planetary perturbations especially by Jupiter can modify some of the originally very elongated orbits into ellipses described in a relatively small number of years—such comets which have circulated already a long time in the vicinity of the sun are the short-period ones and also the "old comets" since they have lost most of their dust material while the new ones, who come near perihelion the first time, have a lot of particles in store and will display long spectacular tails.

In recent years, Dr. Oort has developed these ideas in various articles. They account very well for the random distribution of cometary planes for the long-period "new" ones as well as for the preference for the ecliptical plane and the direct motions which characterize the "old" short period ones. Oort's lecture has given a clearer insight into most phases of the general comet problem although there remain many unsolved questions of detail requiring further study.

Williams Bay, October 4, 1951.

General Notes

"The Story of Palomar" in Switzerland

(EDITOR'S NOTE: The following interesting account of the reception in Europe of the American motion picture "The Story of Palomar" was written by Hans Rohr, Secretary General of the Astronomical Society of Switzerland.)

As soon as the news about the appearance of a new documentary-film illustrating the history of the "Hale"-Reflector was mentioned in American astronomical periodicals, we went to work. The different reports classed the film in a category of its own with regard to contents and presentation. We at once were determined to bring the film to Switzerland, regardless of the trouble involved, as we sensed a great possibility for astronomical propaganda in our country.

The troubles came, endless. Our search for a copy of the film with the rights to be shown abroad went from Pasadena to London, from London to Paris, back again, again to the UNESCO at Paris, from there to the American Legation in Switzerland and to the State Department in Washington—all in vain. In distress we addressed boldly the President of the Technicolor Corporation—who was on a trip abroad—asking for a helping hand. And so, after nearly one and a half years of stubborn search—a habit acquired in parabolising mirrors—the first copy of "The Story of Palomar," sent abroad and lent by courtesy of the State Department, reached Switzerland last fall.

The preliminary organization already prepared, we started to show the film (introduced by a series of the latest astronomical slides from Mount Wilson and Palomar Observatories) in public picture-houses in Switzerland, accompanied by appropriate explanations by a competent lecturer. The sound—narration—on the film, being in English and not in German or French, had to be cut off.

We are happy to state that so far in 55 performances not less than 18,000 people have seen the "Story" in Switzerland. It has been welcomed everywhere by the public and an enthusiastic press. Already the effects of those showings are felt in the life of our local astronomical societies as in the Swiss mother-society itself. Together with the rapidly expanding "disease" of grinding mirrors everywhere in Switzerland, the foundations for a wide interest in astronomy among the public is patiently laid in that way, of course involving a lot of trouble for all concerned, but providing a lot of pleasure at the time.

Better still—and that is the reason for this short communiqué: we were able to induce the school-authorities of the small town of Schaffhausen to present the "Story" to *all* pupils in town, boys and girls, from 13 to 15 years of age. In three special performances, adapted to the understanding of that age, about 1,300 juveniles came to see, mostly for the first time in their lives, a comprehensive picture of the universe and a giant exploratory instrument. The success was complete. Everywhere in the families the film was the main topic of conversation. So great was the interest that in three capacity-performances (evenings) more than 1,200 grown-ups came to see the film too. As a total *more than 10 per cent of the population* of the town (25,000—babies and great-grandfathers included) saw the "Story." The encouraging reports of the school authorities induced other towns in Switzerland to make the film available to their pupils too. So it was shown at Winterthur and Lausanne. The film, being lent to our Society for some time to come, we are organizing for fall and winter an even wider tour of school-performances everywhere in the country. Of course, no profits will be made. All

the showings, organized by a Swiss Centre of Educational Films, are strictly on an educational and no-business basis.

We should be very happy to hear that our modest idea, spreading astronomy deliberately by the help of modern slides and the wonderful "Story" among *juveniles*—the coming men and women of the nation—will find followers in other parts of the planet, helping mankind to understand each other in a better way.

Schaffhausen, Switzerland. HANS ROHR.

International Astronomical Union Appoints Secretary

The Executive Committee of the International Astronomical Union at its recent meeting in Paris decided to appoint an Assistant General Secretary, and to ask Professor P. Th. Oosterhoff, Sterrewacht, Leiden, Netherlands, to act as Assistant General Secretary. Professor Oosterhoff has declared himself willing to do so and has committed himself for the period up to the end of the next General Assembly.

Information regarding the division of the work between the General Secretary and the Assistant General Secretary has been sent to the Adhering Bodies of the IAU and to Presidents of Commissions of the IAU. (Note from Professor Bengt Strömgren, General Secretary, International Astronomical Union, Copenhagen.)

Provisional Sunspot Numbers for September, 1951*

1	46	11	129	21	104
2	47	12	123	22	109
3	48	13	114	23	104
4	55	14	107	24	80
5	54	15	100	25	76
6	84	16	89	26	70
7	77	17	93	27	63
8	91	18	98	28	58
9	108	19	89	29	23
10	113	20	91	30	31

Mean Value September
R = 83.0

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

Red-shift Law. The strange "law of the red-shifts" has been extended 50 percent farther into the depths of space in the first significant results of extra-galactic research to be reported from the 200-inch Hale Telescope at Caltech's Palomar Observatory since it went into operation 20 months ago.

The report was made today by Dr. Milton L. Humason, staff member and Secretary of the Mt. Wilson and Palomar Observatories, operated by the Carnegie Institution of Washington and the California Institute of Technology.

He told the Astronomical Society of the Pacific at its June meeting, held at the University of Southern California, Los Angeles, that in the spectra of light from faint nebulae he had found red-shifts corresponding to speeds ranging up to more than one-fifth the speed of light.

Red-shifts, an apparent lengthening of wave lengths, are widely interpreted as reflecting the velocities of receding stellar systems in a dynamic universe. If this interpretation is correct, the new data would indicate that the universe was expanding at an almost unbelievable rate far out in space.

Dr. Humason's results included red-shifts corresponding to speeds of 31,000,

34,000, and 38,000 miles a second. They were observed in clusters of nebulae—great groups of star systems like our Milky Way, spotted during the National Geographic Society-Palomar Observatory Sky Survey and by the 100-inch telescope on Mt. Wilson—at distances roughly estimated as 300, 330, and 360 million light years from the earth. . . .

These data, Dr. Humason said, indicate that red-shifts continue to increase in direct proportion to the distances of the nebulae observed. This was first discovered by Dr. Edwin P. Hubble, also of the Mt. Wilson and Palomar Observatories, some 22 years ago. He used the scanty data then available, which went out to distances of about seven or eight million light years.

Dr. Humason then extended the observations with the 100-inch Hooker telescope. In 1942 he pushed the law of the red-shifts out to about 250 million light years, the spectrographic limit of that great telescope (half its photographic limit). At this distance the shifts corresponded to speeds of 25,000 miles per second, or approximately one-seventh that of light.

His data, gathered over a period of 10 years, confirmed Dr. Hubble's discovery and permitted the law to be formulated on a more reliable basis. The formulation: As nearly as distances can be estimated, red-shifts increase directly with distance at about 100 miles per second for each million light years.

Now, with the world's largest telescope, Dr. Humason again has extended the observed range of the law—this time by 50 percent. He believes that as soon as suitable nebulae can be found the range can be pushed still farther—out to about 500 million light years.

This project may take several years. Clusters at great distances, suitable for observation, must be found on photographs taken with the 48-inch Schmidt, the 100-inch and the 200-inch telescopes.

Most of the 48-inch Schmidt plates examined for the purpose are being gathered in the course of the Sky Survey, a four-year project of mapping the entire sky visible at Palomar Mountain, San Diego County. Until the telescope went into operation, only about 20 clusters of nebulae were known. But within the last two years several hundred more clusters and groups have been discovered. They were found all the way out to the limit of the Schmidt—some 350 million light years for the brightest nebulae in clusters.

So many have been discovered, in fact, that it is no longer practicable to identify one as "the" Virgo cluster, or even as the Virgo-A or Virgo-B cluster. Each is now identified by its precise location in the sky.

Discovery of clusters beyond the reach of the 48-inch must depend on chance finds by the 100- and 200-inch telescopes. Although they reach deeper into space, their fields of view are much smaller than the Schmidt's. The Schmidt can photograph an area as large as the Big Dipper, while the 200-inch is limited to an area equivalent to one-quarter of the moon.

Such unpredictable finds may accumulate slowly, but they are necessary preliminaries to recording the red-shifts at the top spectrographic range of the Hale telescope, Dr. Humason said.

Red-shifts are measured in a slow and painstaking study of spectrograms. To get them Dr. Humason worked in the prime focus cage suspended in the tube of the huge telescope seven stories above the Observatory floor.

He exposed half-inch square spectroscopic plates to the feeble light from far-off nebulae for four to six hours each. Similar spectrograms of dim objects, though at a lesser distance, would have taken about 25 hours each with the Mt. Wilson 100-inch, the world's second largest astronomical instrument. Photographic

work which Dr. Humason was able to do in three winter nights of reasonably "good seeing" at Palomar might have taken three years on Mt. Wilson.

On the spectroscopic plates light dispersed by a prism is broken down into its component wave lengths in a spectrum only one-tenth of an inch long. Lines in that spectrum indicate the presence of particular wave lengths. With distant objects these lines are shifted about one-twentieth of an inch toward the red, or longer wave length, end of the spectrum.

The shift has been explained by many astronomers as due to the "Doppler effect." This effect, for instance, is what causes the drop in pitch of a locomotive whistle as it speeds into the distance and its sound waves are lengthened in relation to the listener.

If the shift actually is due to the Doppler effect, an implication would be that nebulae everywhere were catapulting away from us in all directions at speeds increasing with their distance—that the entire universe was expanding, like a giant balloon, at a tremendous rate.

The light observed from the most distant cluster studied to date left its source some 360 million years ago. At that time, on the velocity-shift interpretation, the cluster was roaring away at 38,000 miles a second. Since then it may have migrated 70 million light years deeper into space. The message that tells what is happening to it today will reach earth several hundred millions of years from now.

A most important astronomical milestone will have been reached, if at some point in his continuing study, Dr. Humason should find that more distant clusters show red-shifts corresponding to velocity increases of less, or of more, than 100 miles a second for each million light years distance.

Should the red-shift be less than expected in that distant past, the interpretation would be that the rate of expansion of the universe has been speeding up since then. This would mean that the expansion began earlier than now indicated and that the "age of the universe" is more than the two billion years now supposed.

Should the red-shift be greater than expected, the reverse would be true.

Whether this evidence may be found is, of course, impossible to predict. Its interpretation depends, too, on an accurate knowledge of the distances involved and an answer to the question of whether red-shifts actually are velocity-shifts. A possibility exists that the light from far-off objects may have lost energy during its long, lonely journey through space, causing its wave length to increase. In this case, some principle of nature as yet unknown would account for the red-shifts.

However, whether or not they represent speeds of recession, Dr. Humason said, the red-shifts promise to give astronomers a convenient yardstick to establish the distances of new-found objects in space. Once the red-shift is measured, the distance will automatically be known. This will be possible when the range of the law, now regarded as a first approximation, is pushed still farther into the cosmos and after uncertainties in distances assigned to outlying nebulae are removed.

The latter is the province of Drs. Hubble, Walter Baade, and their colleagues. They report that construction of a thoroughly reliable scale of cosmic distance is now under way, using all the resources on Mt. Wilson and Palomar.

The over-all program involves not only photography but also extremely sensitive photoelectric cells developed during World War II. They are being used

to measure the brightness of stars and nebulae several million times fainter than the faintest stars the human eye can see.

Step by step, as outlined by Dr. Hubble, the distance scale will be set up as follows:

Globular clusters, or compact masses of thousands of stars, relatively near the earth, will be used to establish the distance of the great spiral nebula, Messier 31. This will fix the brightness of its Cepheids, or regularly varying giant stars, and its novae, or exploding stars.

Cepheids and novae then will be used to measure the distance of other nebulae as far out as the Ursa Major Cloud and the first cluster found in Virgo. These are roughly six and eight million light years away.

This done, the astronomers will have a collection of about a thousand nebulae of all types. The nebulae themselves can then be calibrated as distance indicators. Their average brightness, variations from the average and the brightest nebulae in clusters will provide a yardstick to measure the distance of more remote clusters.

"When the new scale is available," Dr. Hubble says, "the law of the redshifts can be formulated precisely. It can then be discussed with confidence as a clue to the nature of the universe."

(A news release from the California Institute of Technology, June 19, 1951.)

Defense Program Seeks Astronomers. Wanted: amateur astronomers for work in the defense program.

Chrysler Corporation is looking for astronomers to help produce range finders at the Company's Airtemp Division in Dayton, Ohio, according to C. E. Buchholzer, Airtemp President. The need is for people who have built and operated their own telescopes, Mr. Buchholzer explained, because they usually are neither star-gazers nor abstract mathematicians. Through their hobby they have developed a good practical knowledge of optical instruments.

Announcement of the Office of Naval Research

(Contracts for Research in Astronomy and Astrophysics)

The Office of Naval Research again intends to make available limited funds for the support of pure research in astronomy and astrophysics for the year June 1952-June 1953.

The National Research Council, at the request of ONR, has appointed an Advisory Committee of eminent astronomers to recommend specific projects for support by ONR. The Committee has suggested that the average cost per project should be about $3,000, with a maximum not appreciably in excess of $5,000. It is understood that if a proposal is selected for support by ONR, negotiations will be entered into for a contract between the U. S. Navy and the institution at which the research will be conducted.

The Advisory Committee has recommended that for these relatively small contracts the maximum overhead charges should not be in excess of 10 percent, but all legitimate expenses in connection with the project will be chargeable to the contract.

Applications for the support of projects to be considered this winter should be received at the Office of Naval Research *on or before 10 December 1951*. These should be addressed to Chief of Naval Research, Washington 25, D. C., Attention: Dr. Mina Rees, Director, Mathematical Sciences Division.

Each applicant is requested to submit *ten* copies of all application material (legible carbon copies on thin paper acceptable). Each application should contain a full description of the project, accompanied by a cost breakdown and, if possible, a letter of approval from the institution(s) at which the work will be performed. Letters of recommendation will be helpful to the members of the Advisory Committee in making their appraisal and should be sent by the writer directly to the above address, also by 10 December.

Under the suggested arrangements it will not be possible to pay for the cost of publication of the results of the research. It is, however, understood that research results may be published freely through the usual channels.

Conference on Fluid Mechanics. The Second Midwestern Conference on Fluid Mechanics will be held at The Ohio State University, March 17, 18, and 19, 1952. The scope of the conference is intended to be broad. One of the topics which it is planned to cover is the Dynamics of Interstellar Matter.

Masses of Galaxies. Measurements of forty galaxies, the "island universes" found in the outer stretches of space, show that the Milky Way, the galaxy in which the earth is found, is a relative heavyweight in the heavens. Thornton Page, assistant professor of astronomy in the University of Chicago, reported to the American Astronomical Society in Washington today that the forty galaxies are divided into two groups on the basis of their masses. The heavy group, comprising one-third of the galaxies, has masses averaging 130 billion times the mass of the sun. The lighter group of galaxies, comprising the other two-thirds, have average masses about four billion times the mass of the sun. The mass of our own galaxy, the Milky Way, is about two hundred billion times the mass of the sun. The sun, in turn, has a mass over 330,000 times the mass of the earth.

The measurements of the galaxies were made at the University of Chicago's Yerkes Observatory, and at McDonald Observatory in Texas, which is jointly operated by the University of Chicago and the University of Texas. The galaxies measured were close pairs, and their gravitational pull on each other resulted in a motion which can be detected by a spectrograph. These galaxies are from several million to a hundred million light years away from the earth. Because of this distance, the movements of the galaxies due to gravitational pull can only be observed by the shift of the lines of the elements on a spectrogram as the galaxies move away from or toward the earth.

(New release from the University of Chicago, June 22, 1951.)

Air Almanacs Plan Joint Publication

As from 1953 the *Air Almanac* and the American Air Almanac will become a single publication, under the title of the *Air Almanac*. It will be produced jointly by H. M. Nautical Almanac Office of the Royal Greenwich Observatory, Herstmonceux, and the Nautical Almanac Office of the U. S. Naval Observatory in Washington, to meet the general requirements for air navigation in the United Kingdom, the United States and Canada. The *Air Almanac* will be printed and published separately in England and the United States but will otherwise be identical.

A number of changes have been necessary in both the former publications. None of these have any effect on the principles of tabulation or on the use of the Almanac in navigation.

The National Geographic Society-Palomar Observatory Sky Survey today announced the discovery August 5 of a small comet in the constellation of Ophiuchus, roughly one-one hundredth as bright as the faintest object visible to the naked eye.

The discovery was made by Astronomers Albert G. Wilson and Robert G. Harrington of the California Institute of Technology and the Mount Wilson and Palomar Observatories.

They described the object as a diffuse comet having a nucleus and with a tail about three minutes of arc in length. It is moving toward the sun, they said, and will become brighter and develop a longer tail.

It was discovered on a 14-inch square photographic plate exposed in the 48-inch wide angle telescope on Palomar Mountain for the Sky Survey. Its position at 8:20 P.M., August 5, Pacific Standard Time (or 4:20 o'clock, August 6, universal time) was: right ascension, 1951, 17 hours 35.7 minutes; declination, minus 6 degrees 19.8 minutes of arc.

Its daily motion in right ascension is west, or minus 2.5 minutes of time and in declination is south, or minus 10 minutes of arc. Its apparent magnitude was approximately 10.5, as compared with magnitude 6, the faintest visible to the unaided eye.

Pasadena, California, August 6, 1951.

New Satellite of Jupiter

A telegram from Dr. Ira S. Bowen, Mount Wilson and Palomar Observatories, reports the discovery of a nineteenth magnitude object, probably a new satellite of Jupiter, photographed in the following positions with reference to the position of Jupiter:

1951 U.T.	R.A.	Dec.
	m	
Sept. 29.25	plus 2	plus 0.4
Oct. 4.40	plus 2.5	plus 7.1

The above observations were made on plates taken with the 100-inch telescope by Dr. Seth B. Nicholson and were confirmed on photographs by Dr. L. E. Cunningham with the 60-inch. (From Harvard College Observatory—Announcement Card 1147.)

Of Time—in Verse. In August of this year, Dr. H. W. Farwell, retired Professor of Physics at Columbia University, read in *Physics Today* Professor Dirk Brouwer's article "The Accurate Measurement of Time." Reacting at once to his scientific reading, in poetic vein, Dr. Farwell wrote the bit of verse appearing below. We are indebted to Mr. Neal J. Heines of the American Association of Variable Star Observers (Solar Division, Paterson, New Jersey) for making this whimsical and philosophical poem available for publication in POPULAR ASTRONOMY.

TIME

The scientist pretends to measure time,
  And states his proof with cabalistic sign.
He gives detailed account of bells that chime,
  Of ancient dials, clepsydras so fine.

He tells what Galileo did in church;
  How Huyghens' genius solved a paradox;
How crystal oscillators aid research;
  And ends with praise for those atomic clocks.

Perhaps the truth is just as he predicts,
  But other men have measured hours and days,
And their impression clearly contradicts
  The law he claims that every star obeys.

What mother, list'ning for the postman's walk
  Will say that all the minutes are alike?
How many sleepless nights are spent in talk,
  While waiting, hoping that the clock will strike?

With other folks it's quite another way,
  For them the speeding hours are far too short.
The clocks run fast when busy children play;
  Still faster, holidays of any sort.

The boy is ever tired of sluggish years
  That hold him back from man's estate.
And yet the father thinks his son appears
  To age much faster than appropriate.

For long the keenest minds have realized
  That even time can vary now and then.
In Arden's forest, Rosalind, disguised,
  Could tell Orlando much of time and men.

Then measure truly, Science, if you can,
  The frequent fleeting hour, the longest day;
Or how the seconds dragged, or minutes ran;
  But never claim they'll always stay that way.

—H. W. FARWELL.

Book Reviews

Borderlands of Science, by Alfred Still. (Philosophical Library, Inc., 15 E. 40th St., New York City, 1951. 424 pp., $3.75.)

The Philosophical Library has published a series of distinguished books, among which the volume under review seems out of place. The title suggests the frontier region, where scientific research and discovery are going on. Actually the book is a discussion of "supernatural phenomena" such as magic, witchcraft, the divining rod, levitation, clairvoyances, and telepathy.

Such phenomena have been extensively investigated by amateurs and by scientists from anthropologists to zoologists. The area of unexplained phenomena has diminished so steadily that it has come to be accepted that there is no area that is in principle unexplainable. Accordingly one might expect an account of how science has gradually conquered superstition. One gets glimpses of this process, but the tone of the book is mystical rather than scientific. The reader finds broad and careless generalizations, scattered bits of information, confusion of terms, hints at the reality of magic, cryptic comments, and careless jibes (*e.g.*, at religion and at science) instead of the wealth of intriguing and verified information which could be presented. The following quotations partially illustrate these judgements: "It is generally recognized that man, when asleep or in the subjective condition, is safe from attacks by wild animals" (p. 325). "Mrs. David-Neel, whose word cannot be doubted, has herself touched a phantom. . ." (p. 39). "The modern physicist has little faith in the curative properties of magnetism, so we —being modern—may assume that Paracelsus affected his cures by magic." (p. 63). "Modern mathematics pays little attention to axioms. . ." (p. 362). "This period

was followed by the Dark Ages. . . . Nobody wanted to know why the world of men was as it seemed to be. . . . There was no appeal to reasons; no scepticism."

The book ends with what appears to be an appeal for the merging of science and mysticism. The author may have made a contribution to the literature of mysticism or to the gentle art of pulling the public's leg, but not to the scientific understanding of the phenomena discussed.

Carleton College. KENNETH O. MAY.

Rockets, Missiles, and Space Travel, by Willy Ley. (The Viking Press, 18 E. 48th St., New York 17, N. Y., June 29, 1951, 436 pp., $5.95.)

For those who would like to discover how close we are to interplanetary travel, here is a thoroughly fascinating book. The author traces the development of rockets from the earliest solid-fuel "sky rockets" to the V-2 and the other liquid-fuel rockets of the present. The possibility of using atomic energy is also considered. Actual performance data are given in well-labeled tables (in both metric and English units).

Although there is a wealth of technical information in this book (some wisely relegated to an extensive appendix), it is far from being a dry, technical work. The style is conversational. Numerous anecdotes are included. Because the work on rockets has been done by so many different people and with so many different objectives in view, the book is necessarily somewhat rambling. The author has done an excellent job in showing the relationship of the work of the various investigators.

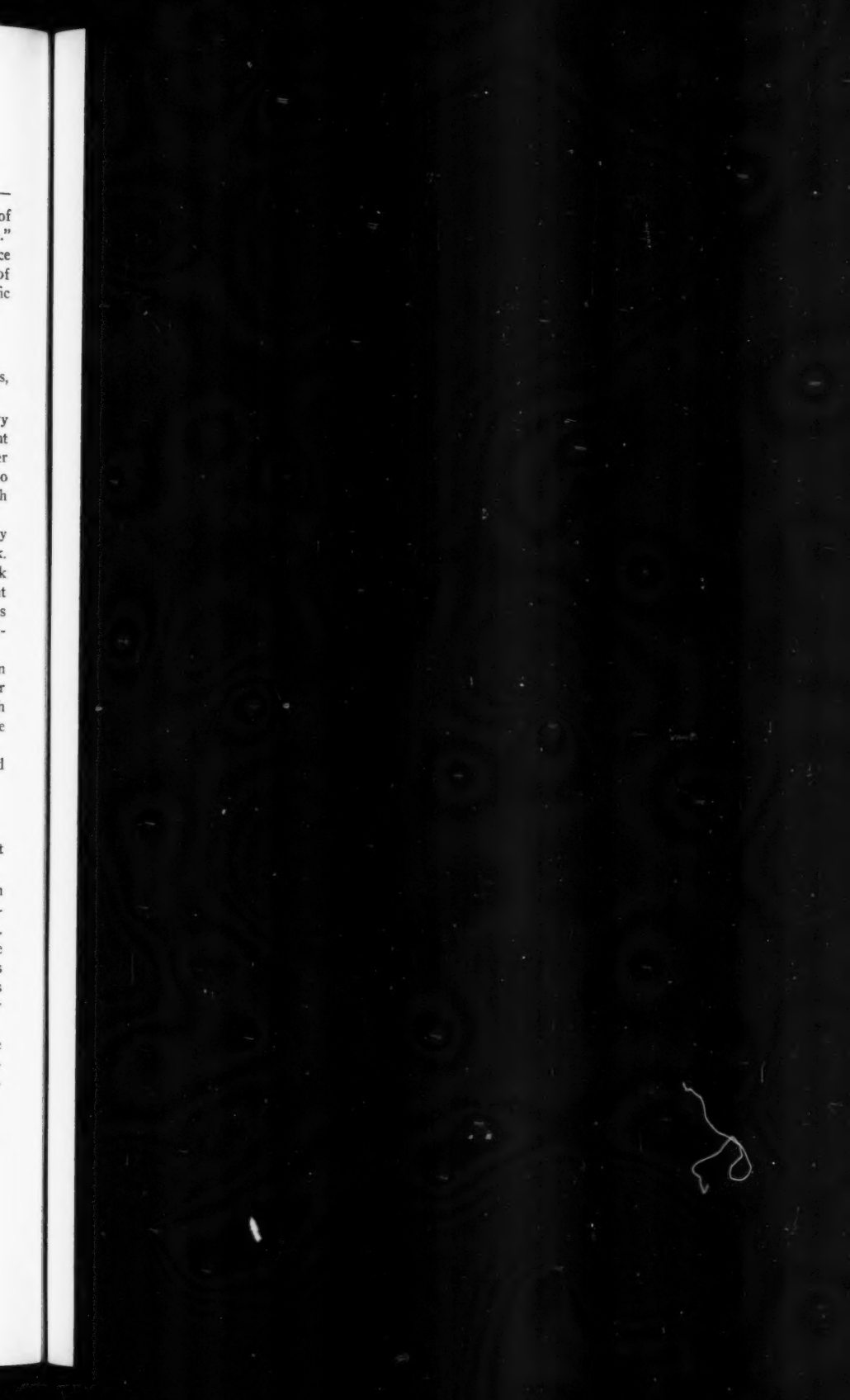
Of the most interest to those with an astronomical bent is the presentation of data on "possible" trips to the moon, Mars, and Venus. Tables are given for time of transit for various initial assumptions as to rocket performance. Enough background material is presented for the reader to see what factors enter into the calculations, even though the calculations themselves are omitted.

As a final touch the author presents an extensive bibliography of books and articles in English, German, French, Italian, Russian, Spanish, and Dutch.

Carleton College. ROBERT L. HENRY.

First Course in Probability and Statistics, by J. Neyman. (Henry Holt and Co., 257 Fourth Ave., New York 10, N. Y., 1950. 350 pp., $3.50.)

In recent years, mathematical statistics has been playing an increasing role in astronomy as in all other sciences. At the same time, the theory has been tremendously expanded, made more rigorous, and reorganized in its foundations. This book, while intended as an undergraduate text and not requiring knowledge of calculus, presents the basic concepts of modern probability and statistics. Its author is one of the founders of the Neyman-Pearson theory of testing hypotheses and a leading representative of the school of statisticians who identify probability with operationally defined relative frequency.

Following an interesting discussion of statistics as the theory of inductive behavior, the basic concepts of probability, random variables, frequency distributions, and testing hypotheses are developed with great conceptual clarity. Because of its illuminating ideas, the book is of interest to the professional statistician as well as to the beginning student and to the layman who desires insight in this important field. It will probably become a classic, not only as a text but as a contribution to the foundations of the subject.

Carleton College. KENNETH O. MAY.